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ALVIN L. YOUNG, Major, USAF
Consultant, Environmental Sciences

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Comparison Test of Defoliants

by

Robert E. Klein, Capt, USAF

Edward T. Harrigan, 1st Lt, USAF

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DIRECTORATE OF TEST AND EVALUATION

ARMAMENT DEVELOPMENT AND TEST CENTER

AIR FORCE SYSTEMS COMMAND • UNITED STATES AIR FORCE

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APPENDIX III - Biological Effectiveness of Stull Bifluid and Orange

APPENDIX IV - Comparative Cost Analysis of the Agent Orange Defoliant Systems

APPENDIX V - Spread Factor Study of Drops of Orange and Stull Bifluid Defoliants on Kromekote Cards and Plant Leaves

AFATL-TR-68-122

APPENDIX III

Biological Effectiveness of Stull Bifluid and Orange

Woodland Hurtt
Robert A. Darrow
Plant Sciences Laboratories
Fort Detrick

TECHNICAL REPORT AFATL-TR-68-122

OCTOBER 1968

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AIR FORCE ARMAMENT LABORATORY
AIR FORCE SYSTEMS COMMAND
EGLIN AIR FORCE BASE, FLORIDA

BIOLOGICAL EFFECTIVENESS OF

STULL BIFLUID AND ORANGE

Woodland Hurtt
Robert A. Darrow

FOREWORD

This report was prepared by the Plant Physiology Division, Plant Sciences Laboratories, Department of the Army, Fort Detrick, Frederick, Maryland under MIPR PG-8-72, Project 5172, Comparative Test of Defoliants. The work was sponsored by the Air Force Armament Laboratory (AFATL), Biological-Chemical Division, Eglin Air Force Base, Florida. Mr. Marshall Solomon (ATCB) was the Air Force Project Engineer during the program.

This report covers laboratory and greenhouse evaluation studies initiated 12 June 1968 and completed 12 September 1968. Three monthly contract status reports were submitted to Mr. Solomon during the 90-day program.

Acknowledgment is given to Mr. Walter J. Hart and CPT Charles A. Vile, Plant Physiology Division, for assistance in the conduct of the experiments. Appreciation is expressed to Dr. James W. Brown for invaluable assistance in the preparation of this report. Statistical analyses of all data were furnished by Mrs. Marian W. Jones, Biomathematics Division. Equipment and technical assistance for droplet applications with the spinning-cup drop generator were provided by Physical Science Division. Test plant materials were furnished to that division for coordinated research on spread factor determinations on leaf surfaces.

JOHN E. HICKS, Colonel, USAF
Chief, Biological-Chemical Division

ABSTRACT

A comparison of biological effectiveness of Stull Bifluid and ORANGE was made by bioassay techniques using Black Valentine beans, Red Kidney beans, silver maple and green ash as test plants. Single and multiple droplet applications were made at sublethal dosage rates of undiluted herbicide with micrometer syringes and the spinning-cup applicator. Evaluations of growth inhibition of bean plants in terms of fresh weight, dry weight, and/or height showed no difference between Stull Bifluid and ORANGE at the 5% significance level. Variables in seven experiments (bean plants) included size and age of plants, number of treated leaves, position of droplets on leaves, size of drops, and micrometer-syringe versus spinning-cup method of application. Studies with the spinning-cup applicator with comparable total volumes applied in three droplet sizes (125, 250, and 500 μ) showed no difference in response between Stull Bifluid and ORANGE. The smaller droplet sizes gave greater growth inhibition with both materials. Single and multiple droplet applications on seedling trees with the micrometer syringe technique showed ORANGE to be more effective than Stull Bifluid at the 5% significance level in two of three experiments. In the third experiment, there was no significant difference in the two herbicides. In the standard primary screening program with six crop species, additional comparisons among (i) ORANGE, (ii) Stull Bifluid, and (iii) the two Stull Bifluid components, Bifluid #1 and Bifluid #2, at 0.1 and 1.0 pound per acre showed no apparent differences.

TABLE OF CONTENTS

LIST OF TEXT TABLES

LIST OF APPENDIX TABLES

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SECTION I

INTRODUCTION

The primary objective of this research effort was to compare the biological effectiveness of ORANGE[1] and Stull Bifluid.[2] The purpose of these studies was to assess the claim of greater spread for Bifluid drops on foliage, thus permitting enhanced absorption of defoliant. Such a comparison of effectiveness would reflect any differences attributable to enhanced absorption and would also reflect any difference due to differential transport within the plants following foliar absorption.

To compare the biological effectiveness of Stull Bifluid in contrast with agent ORANGE, two varieties of bean plants were selected as the species of choice because of the mass of available knowledge concerned with their responses to herbicides.

In order to obtain a broader base of data for comparing ORANGE and Stull Bifluid, additional studies were conducted with seedling trees as the test plants. Green ash (*Fraxinus pennsylvanica*) or silver maple (*Acer saccharinum*) trees were treated with equal volumes of ORANGE or Stull Bifluid and inhibition of growths in height and fresh weight were determined.

Data from a number of preliminary studies were used as the basis for selecting the proper doses of the two defoliants used in these experiments.

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[1] 50% *n*-butyl ester of 2,4-dichlorophenoxyacetic acid and 50% *n*-butyl ester of 2,4,5-trichlorophenoxyacetic acid.

[2] Stull Bifluid, as used in this paper, refers to a mixture containing approximately 90% ORANGE and 10% additives.

SECTION II

APPROACH AND GENERAL TECHNIQUES

Phaseolus vulgaris L. var. Black Valentine or Red Kidney beans were used for all of the studies contained in the first seven experiments. Four seeds were planted in each pot of standard greenhouse soil mix. Approximately one week later, the plants were thinned to one per pot in order to obtain uniformity of plant material. Because of the effect of environment and depth of planting on germination and growth, day 1 was defined as the day the plants emerged from the soil rather than the day of planting.

At varying intervals following treatment, the plants were harvested at either the primary leaf node or the cotyledonary node, and fresh weights were determined. In certain instances, dry weights were determined by drying the plant material in a forced-draft oven at 95 C for a minimum of 24 hours. The concept of using fresh weight (or inhibition of fresh weight production) as a criterion of effect is well founded in the literature and is generally accepted. It was particularly appropriate for these studies because the imposed requirement of working with nondiluted defoliants virtually assured a desiccating effect upon the test plants, which in turn was reflected by loss of water and decreased fresh weight of the plant material. Representative plants from each treatment were photographed in both color and black and white on the day of harvest as an additional source of observational information. Frequently, photography also was employed as a tool midway through the course of an experiment when responses were being produced that were of special interest, such as transient responses or responses that might be lost if the plants progressed towards a more severe effect.

Very diverse environmental parameters were encountered during the course of these studies, and this should strengthen the comparison of ORANGE and Stull Bifluid. The mean recorded temperature at the time of treatment over all experiments was 34 C, with a range of 27 C to 40 C. The mean relative humidity at time of treatment was 39%, and the range was 25% to 56%. Light intensity varied from 990 ft-c to 8,850 ft-c, with a mean value at the time of treatment of 3,700 ft-c.

ORANGE was used without the addition of the dye (Automate Red B) supplied by Eglin AFB in all but one experiment, in which case it was added to ORANGE to make a 1% solution (v/v). Bifluid #2 and Bifluid #1 were mixed in the prescribed ratio of 15:1 to produce the standard Stull Bifluid. The two Bifluids were mixed immediately prior to the start of an experiment, and a new mix was used for each experiment.

ORANGE and Stull Bifluid were applied to the test plants by micrometer syringes or by the spinning-cup applicator. RGI micrometer syringes equipped with 21-gauge needles were used to apply volumes of defoliant ranging from 0.05 to 0.5 μl. Hamilton PB600 repeating dispensers with Hamilton #7000 syringes (1-μl capacity) and 25-gauge needles were used for the application of 0.02-μl volumes of defoliant. Application was made by holding the syringe vertically over the vein of the leaf to which the defoliant was to be applied, pressing the button (or turning the micrometer dial), and touching off the expelled liquid on to the leaf vein. Application by the spinning cup, described in greater detail later in this report, resulted in random drops on the leaves of the test plants in contrast to the veinal applications with the micrometer syringes.

The two types of experimental design employed in these studies were (i) the completely randomized experiment, in which the plants were placed at random on the bench in the greenhouse, and (ii) the randomized block, in which the treatments (including a control) were randomized within each block. A block was a designated portion of each greenhouse bench. The data contained in this report were statistically analyzed by Biomathematics Division.

SECTION III

EXPERIMENT 1: A PRELIMINARY STUDY ON SUBLETHAL QUANTITIES OF ORANGE APPLIED TO RED KIDNEY BEANS

1. OBJECTIVE

In order to obtain dose-response information for subsequent comparisons of Stull Bifluid and ORANGE, this study was designed (i) to determine the approximate volume of defoliant required, and (ii) to compare the effects of different numbers of drops versus different drop sizes, while maintaining a constant total volume.

2. METHODS

The RGI syringes were employed to apply 0.1, 0.2, 0.4, and 0.8 µl of ORANGE to 12-day-old Red Kidney beans in a completely randomized design.

The array of drop sizes, numbers of drops, and total volume of ORANGE per plant is shown in Table I. The plants were harvested after 14 days, and both fresh and dry weights were obtained.

TABLE I. EFFECT OF VARYING SIZE AND NUMBER OF DROPS OF ORANGE ON FRESH AND DRY WEIGHT REDUCTION OF RED KIDNEY BEANS[a]

Drops per plant			Fresh wt, g		Dry wt, g	
No.	Size, µl	Total µl	Mean[b]	% Inhibition	Mean[b]	% Inhibition
2	0.05	0.1	13.60	34.5	1.538	40.7
2	0.1	0.2	9.72	53.2	1.080	58.4
4	0.05	0.2	7.06	66.0	0.894	65.5
2	0.2	0.4	9.01	55.6	1.038	60.0
4	0.1	0.4	3.23	84.5	0.646	75.1
2	0.4	0.8	5.15	75.2	0.900	65.3
4	0.2	0.8	4.81	76.8	0.794	69.4
8	0.1	0.8	1.18	94.3	0.564	78.3
Control			20.77	0	2.594	0

a. Plants were 12 days old when treated on primary leaves and were harvested 14 days later.

b. All data are means for 5 plants.

3. RESULTS AND DISCUSSION

Fresh weight and dry weight are in rather close agreement in terms of relative per cent reduction of weight within the equal volume applications (Table I). It appears that eight 0.1-μl drops are more effective than either two or four drops of a larger size. The same trend exists in all comparisons; e.g., four 0.1-μl drops are more effective than two 0.2-μl drops. The data were analyzed separately for each total volume; i.e., 0.2, 0.4, and 0.8 μl. Because of the variability within treatments, only the 0.4-μl comparison was significant. Both fresh and dry weights showed that four 0.1-μl drops were more effective than two 0.2-μl drops.

SECTION IV

EXPERIMENT 2: COMPARISONS BETWEEN ORANGE AND STULL BIFLUID, USING THREE DROP SIZES BUT CONSTANT TOTAL VOLUME, ON RED KIDNEY BEANS

1. OBJECTIVE

Comparisons of biological effectiveness of ORANGE and Stull Bifluid were made for three droplet sizes: two 0.4-μl drops, four 0.2-μl drops, and eight 0.1-μl drops. The total volume applied to each plant was 0.8 μl.

2. METHODS

A completely randomized design was used with eight 19-day-old Red Kidney beans per treatment. The defoliants were applied to the primary leaves with the RGI syringes in numbers and sizes of drops as indicated above. The plants were harvested 12 days after treatment and fresh weights were determined.

3. RESULTS AND DISCUSSION

When the data for the numbers of drops were pooled (Table II) and analyzed, the values obtained for ORANGE and for Stull Bifluid were not shown to be significantly different. In the analysis, neither defoliants nor drops were significant at the 5% level, nor was the interaction between drops and defoliants.

TABLE II. EFFECT OF VARYING SIZE AND NUMBER OF DROPS OF ORANGE AND STULL BIFLUID, BUT WITH TOTAL VOLUME HELD CONSTANT, ON INHIBITION OF FRESH WEIGHT OF RED KIDNEY BEANS[a]

2 Drops[b]		4 Drops[b]		8 Drops[b]		Drops pooled	
Mean[c]	% Inhib.	Mean[c]	% Inhib.	Mean[c]	% Inhib.	Mean[c]	% Inhib.
ORANGE							
32.09	31.0	34.03	26.8	31.90	31.4	32.78	29.5
Stull Bifluid							
31.10	33.1	32.50	30.1	25.99	44.1	30.13	35.2
Defoliants pooled							
31.60	32.0	33.15	28.7	28.95	37.7	-	-

a. Plants were 19 days old when treated on primary leaves and were harvested 12 days later.

b. Indicates the total number of drops per plant; the total volume applied per plant was constant, 0.8 μl.

c. All data for ORANGE and Stull Bifluid are the mean fresh weights (grams) for 8 plants; thus, the pooled data reflect means for 24 and 16 plants for the drops and defoliants, respectively.

SECTION V

EXPERIMENT 3: EVALUATION OF THE EFFECTS OF RED DYE ON THE ACTIVITY OF ORANGE APPLIED TO PRIMARY LEAVES OF RED KIDNEY BEANS

1. OBJECTIVE

It was necessary to know if red dye influenced the activity of ORANGE because it would be used later in a spinning-cup experiment.

2. METHODS

Red Kidney beans were used in this study. Plants were treated on the primary leaves, one 0.5-μl drop per leaf, when they were 15 days old. Treatments consisted of ORANGE or ORANGE plus 1% Automate Red B dye (v/v).

3. RESULTS AND DISCUSSION

No difference was shown between ORANGE with and without the dye (Table III).

TABLE III. EFFECT OF DYE ON THE ACTIVITY OF ORANGE FROM APPLICATION OF 1.0 MICROLITER ON RED KIDNEY BEANS[a]

Treatment	Mean fresh weight,[b] g	% Inhibition
Control	46.10	0
ORANGE + dye[b]	33.13	28.1
ORANGE	32.85	28.8

a. Plants were 15 days old when treated on primary leaves and were harvested 14 days later.
b. Control datum is mean for 10 plants; all other data are means for 7 plants.
c. ORANGE + Automate Red B dye at 99:1 (v/v).

SECTION VI

EXPERIMENT 4: THE EFFECTIVENESS OF ORANGE AND STULL BIFLUID APPLIED TO COMPOUND LEAVES OF RED KIDNEY BEANS

1. OBJECTIVE

The objective of this study was to compare the activity of ORANGE and Stull Bifluid by treating the trifoliolate leaflets.

2. METHODS

A completely randomized design with 20 replications was employed. The Red Kidney bean plants were treated with the RGI syringes when they were 16 days old. Treatment consisted of application of a total of six 0.2-µl drops to each plant (one drop on each leaflet of the lower two compound leaves). The plants were harvested 15 days later, and both fresh and dry weights were determined.

3. RESULTS AND DISCUSSION

At the 5% level of probability, no significant difference was found between the ORANGE and Stull Bifluid treatments (Table IV).

TABLE IV. INHIBITION OF GROWTH OF RED KIDNEY BEANS FROM APPLICATIONS OF 1.2 MICROLITERS OF ORANGE OR STULL BIFLUID[a]

Treatment	Dry weight,[b] g	% Inhibition
Control	5.92	0
ORANGE	2.62	55.8
Stull Bifluid	3.00	49.3

a. Plants were 16 days old when treated and were harvested 15 days later. One 0.2-µl drop was applied to each leaflet of the lower two compound leaves.
b. All data are the means of 19 plants.

SECTION VII

EXPERIMENT 5: A COMPARISON OF THE GROWTH INHIBITION OF RED KIDNEY BEANS TREATED WITH 0.02-MICROLITER DROPS OF ORANGE OR STULL BIFLUID

1. OBJECTIVE

The specific objectives of this study were to (i) compare the effectiveness of ORANGE and Stull Bifluid by multiple applications of very small volumes of these liquids and (ii) to ascertain if an operator-syringe effect existed with these previously untried syringes.

2. METHODS

Two matched Hamilton repeating syringes were used to make leaf applications of 0.02-μl volumes of liquid. Each 0.02-μl volume of liquid dispensed from these syringes would be equivalent to the volume of a spherical drop with a diameter of 350 microns.

Because of the anticipated greater effect from treating many leaves, large plants were used. Sixteen-day-old Red Kidney beans with three fully expanded compound leaves were selected. A randomized block design was used with a total of 8 blocks. Each block was split into two sub-blocks. Each sub-block contained one control plant, one plant treated with ORANGE, and one plant treated with Stull Bifluid. Each block contained an operator versus syringe comparison as well as an ORANGE versus Stull Bifluid comparison.

Because there were so many new variables in this experiment, both fresh and dry weight data were obtained when the plants were harvested 10 days after treatment.

3. RESULTS AND DISCUSSION

Means are given in Table V. Analyses of variance did not disclose a significant difference between ORANGE and Stull Bifluid. Neither were syringes shown to differ.

The only significant difference (5% level) occurred in fresh weights among blocks. A block effect is a positional one, which indicates there may have been differences with regard to plant location on the greenhouse bench.

TABLE V. THE EFFECT OF 37 0.02-MICROLITER DROPS OF ORANGE OR STULL BIFLUID ON THE PRIMARY AND COMPOUND LEAVES OF RED KIDNEY BEANS AND A COMPARISON OF OPERATOR VERSUS SYRINGE EFFECTS[a]

Treatment	Fresh wt		Dry wt	
	Mean[b]	% Inhibition	Mean[b]	% Inhibition
Control	20.48	0	2.950	0
Mean of two syringes				
ORANGE	10.12	50.6	1.925	34.8
Stull Bifluid	9.06	55.8	1.900	35.6
Combined	9.59	53.2	1.914	35.1
Mean of two defoliants				
Syringe No. 1	8.82	57.0	1.955	33.7
Syringe No. 2	10.36	49.4	1.874	36.5

a. Plants were 16 days old when treated and were harvested 10 days later. For each compound, five drops were applied per primary leaf and three drops per leaflet of the lower three compound leaves on each plant. In the operator versus syringe comparison, one operator used one syringe.

b. The data for the controls, ORANGE, and Stull Bifluid are the means for 16 plants; all other data are means for 32 plants.

SECTION VIII

EXPERIMENT 6: COMPARATIVE ACTIVITIES OF ORANGE AND STULL BIFLUID APPLIED AT A RATIO OF 1:1.1 (V/V) ON RED KIDNEY BEANS

1. OBJECTIVE

Because ORANGE is the major active ingredient and constitutes about 90% of the Stull Bifluid material, a test was performed applying a 10% greater volume of Stull Bifluid to obtain applications of equal volumes of ORANGE to compare their activities.

2. METHODS

In order to compensate for this approximate 10% dilution of ORANGE, the RGI syringes were employed to apply a total of 0.5 µl of ORANGE and 0.55 µl of Stull Bifluid to 18-day-old Red Kidney beans. Five drops were applied to each plant by placing one drop on each main vein of each primary leaf and one drop on each main vein of each leaflet of the lowermost compound leaf. This application eliminated any possibility of an interaction between main and secondary leaf veins. The plants were harvested 11 days after treatment, and fresh weight determinations were made. The design of the experiment was a randomized block with 13 replications.

3. RESULTS AND DISCUSSION

The results (Table VI) and statistical analysis did not indicate a significant difference between the effectiveness of ORANGE and Stull Bifluid.

The statistical analysis showed differences between blocks to be significant, and this was interpreted as a positional effect on the greenhouse bench.

TABLE VI. THE EFFECT OF APPLICATION OF 0.5 MICROLITER OF ORANGE OR 0.55 MICROLITER OF STULL BIFLUID ON THE GROWTH OF RED KIDNEY BEANS[a/]

Treatment	Fresh weight,[b/] g	% Inhibition
Control	8.71	0
ORANGE	2.73	68.7
Stull Bifluid	2.95	66.1

a. Plants were 18 days old when treated and were harvested 11 days later. On each plant, either five 0.1-µl drops of ORANGE or five 0.11-µl drops of Stull Bifluid were applied; in all cases, the five drops were applied on main veins, one drop on each of the two primary leaves, and one drop on each of the leaflets of the lowermost compound leaf.

b. All data are the means for 13 plants.

SECTION IX

EXPERIMENT 7: THE EFFECTIVENESS OF ORANGE AND STULL BIFLUID APPLIED TO BLACK VALENTINE BEANS AT THREE DROPLET SIZES BY A SPINNING-CUP APPLICATOR

1. OBJECTIVE

The specific objective of this experiment was to compare the effectiveness of ORANGE and Stull Bifluid from applications of free-falling drops of three sizes (500, 250, and 125 μ), with total volume held constant.

2. METHODS

On the basis of a rather extensive preliminary experiment with applications to bean plants with the spinning-cup apparatus, it was determined that approximately 0.57 μl of ORANGE or Stull Bifluid, when applied as 250-μ drops with a total application of approximately 70 drops gave a good response on the test plants. Volume calculations showed that 8.7 drops would be required if 0.57 μl was to be applied to the plants in the form of 500-μ drops. Similarly, it was determined that 564 drops with diameters of 125 μ would be required to give a 0.57 μl dosage. These values were established as the criteria for treatment.

Droplet applications were made to 9-day-old Black Valentine beans with the spinning-cup apparatus. As the plants were treated with the spinning-cup apparatus, Physical Science Division made concurrent spherical-drop-size measurements. The plants were shielded so that only the primary leaves were treated. The actual number of drops on each leaf was determined as well as the total number of drops per plant. These counts were made to equalize treatments. Up to 28 plants were treated with each drop size, and later calculations determined the actual microliter dosage. After treatment the plants were placed in a random pattern on greenhouse benches. The plants were harvested nine days later, and fresh weights were obtained.

In order to obtain a balanced design of 10 plants per treatment for later statistical analysis and to secure uniform treatments, three criteria were applied to the three treatment parameters. These criteria were tolerances for total microliters, number of drops, and drop size. Plants receiving the most uniform treatments were selected from those listed in Appendix I, Tables I-1 through I-6, and are presented in Tables I-7 through I-9. The control plants used in this experiment are shown in Table I-10.

3. RESULTS AND DISCUSSION

Tables VII, VIII, and IX show that the actual volume of defoliant applied was extremely close to the value of 0.57 μl. Likewise, the desired spherical diameter was very close to the selected values. Obviously, there was more deviation from the desired number of drops per plant because of the difficulty in determining exactly when a plant had received the correct number of drops.

Tables VII, VIII, and IX also show the leaf area contacted by the defoliants; these values were calculated using the spread factors for the respective defoliants on Black Valentine bean plants for each of the three nominal drop sizes tested. The spread factors were supplied by Physical Science Division.

TABLE VII. SUMMATION OF TREATMENT PARAMETERS FOR APPLICATION ON BLACK VALENTINE BEANS OF ORANGE AND STULL BIFLUID DROPS WITH NOMINAL SPHERICAL DIAMETERS OF 125 MICRONS[a]

Plant no.	Drop diameter, μ	Dose: No. of drops	Dose: Total μl	Leaf area contacted by defoliant,[b] mm^2
		ORANGE		
77	112	578	0.428	14.55
78	112	604	0.447	15.21
79	112	619	0.458	15.58
70	140	405	0.567	15.93
65	140	439	0.615	17.27
75	126	627	0.627	19.98
68	140	460	0.644	18.10
69	140	466	0.652	18.33
61	126	686	0.686	21.86
80	112	958	0.709	24.12
Mean	126.0	584.2	0.583	18.09
SD	12.5	153.7	0.098	2.94
$\bar{X} \pm$ SD[c]	114-138	430-738	0.485-0.681	15.15-21.04
		Stull Bifluid		
141	114	585	0.456	14.12
143	114	596	0.465	14.38
142	114	609	0.475	14.70
146	114	664	0.518	16.02
131	122	589	0.560	16.28
129	122	609	0.579	16.83
133	122	610	0.580	16.86
127	122	700	0.665	19.35
125	122	749	0.712	20.70
136	141	475	0.712	17.54
Mean	120.7	618.6	0.572	16.68
SD	7.7	70.1	0.092	2.01
$\bar{X} \pm$ SD	113-128	548-689	0.480-0.664	14.67-18.69

a. Drops applied by the spinning-cup applicator on 9-day-old plants.
b. Calculated from number of drops, sizes of drops, and spread factors. The spread factors for ORANGE and Stull Bifluid were 1.599 and 1.538, respectively. Spread factors and drop diameters were determined by Physical Science Division.
c. SD = standard deviation; $\bar{X}$ = mean.

TABLE VIII. SUMMATION OF TREATMENT PARAMETERS FOR APPLICATION ON BLACK VALENTINE BEANS OF ORANGE AND STULL BIFLUID DROPS WITH NOMINAL SPHERICAL DIAMETERS OF 250 MICRONS[a]

Plant no.	Drop diameter, μ	Dose		Leaf area contacted by defoliant,[b] mm^2
		No. of drops	Total μl	
ORANGE				
85	260	69	0.635	9.30
87	260	68	0.626	9.17
88	260	58	0.534	7.82
89	260	68	0.626	9.17
90	260	59	0.543	7.96
93	260	64	0.589	8.63
94	260	64	0.589	8.63
97	260	65	0.598	8.76
98	260	59	0.543	7.96
101	260	67	0.616	9.03
Mean	260	64.1	0.590	8.59
SD	0	3.9	0.036	0.62
$\bar{X} \pm$ SD[c]	-	60-68	0.554-0.626	7.96-9.21
Stull Bifluid				
150	256	68	0.598	9.71
151	256	63	0.554	9.00
154	272	57	0.598	9.19
155	236	78	0.538	9.46
158	236	70	0.483	8.49
159	236	71	0.490	8.62
161	236	70	0.483	8.49
162	236	72	0.497	8.74
163	236	81	0.559	9.83
169	236	78	0.538	9.46
Mean	243.6	70.8	0.534	9.10
SD	12.3	6.8	0.041	0.48
$\bar{X} \pm$ SD	231-256	64-78	0.493-0.575	8.62-9.58

a. Drops applied by the spinning-cup applicator on 9-day-old plants.
b. Calculated from number of drops, sizes of drops, and spread factors. The spread factors for ORANGE and Stull Bifluid were 1.594 and 1.666, respectively. Spread factors and drop diameters were determined by Physical Science Division.
c. SD = standard deviation; $\bar{X}$ = mean.

TABLE IX. SUMMATION OF TREATMENT PARAMETERS FOR APPLICATION ON BLACK VALENTINE BEANS OF ORANGE AND STULL BIFLUID DROPS WITH NOMINAL SPHERICAL DIAMETERS OF 500 MICRONS[a]

Plant no.	Drop diameter, μ	Dose: No. of drops	Dose: Total μl	Leaf area contacted by defoliant,[b] mm^2
		ORANGE		
102	495	9	0.572	5.55
103	495	9	0.572	5.55
104	495	9	0.572	5.55
106	505	9	0.607	5.77
112	498	9	0.582	5.61
113	498	9	0.582	5.61
115	498	9	0.582	5.61
118	498	9	0.582	5.61
119	498	10	0.647	6.24
122	502	9	0.596	5.70
Mean	498.2	9.1	0.589	5.68
SD	3.0	0.3	0.22	0.20
$\bar{X}$ ± SD[c]	495-501	8.8-9.4	0.567-0.612	5.48-5.88
		Stull Bifluid		
171	508	9	0.618	5.38
173	508	9	0.618	5.38
177	508	9	0.618	5.38
178	508	9	0.618	5.38
181	482	9	0.527	4.84
185	482	9	0.527	4.84
187	482	9	0.527	4.84
189	482	9	0.527	4.84
190	482	9	0.527	4.84
175	508	9	0.618	5.38
Mean	495.0	9.0	0.572	5.11
SD	13.0	0	0.046	0.27
$\bar{X}$ ± SD	482-508	-	0.527-0.618	4.84-5.38

a. Drops applied by the spinning-cup applicator on 9-day-old plants.
b. Calculated from number of drops, sizes of drops, and spread factors. The spread factors for ORANGE and Stull Bifluid were 1.790 and 1.717, respectively. Spread factors and drop diameters were determined by Physical Science Division.
c. SD = standard deviation; $\bar{X}$ = mean.

Means and 95% confidence limits are shown in Table X. It is obvious from this table that the growth inhibitions caused by ORANGE and Stull Bifluid did not differ significantly at any of the three drop sizes tested.

The values for pooled defoliants and the individual means for each defoliant clearly show that growth inhibition decreased as droplet size increased (Table X). Inhibition of fresh weight from 500-μ drops was markedly less than from 125- or 250-μ drops. Presumably, the greater the number of drops of sizes used in this experiment, the greater the area of the plant exposed to absorption of the defoliant.

TABLE X. EFFECT OF THREE NOMINAL DROP SIZES OF ORANGE AND STULL BIFLUID ON THE GROWTH OF BLACK VALENTINE BEANS WHEN THE TOTAL VOLUMES WERE HELD CONSTANT AND NUMBERS AND SIZES OF DROPS WERE VARIED[a]

Treatment	Mean drop diameter, μ	Fresh weight Mean, g	95% Confidence limits	% Inhibition
Control	---	3.728	3.417 - 4.039	0
ORANGE				
125μ	126.0	0.779	0.590 - 0.968	79.1
250μ	260.0	1.332	0.745 - 1.919	64.3
500μ	498.2	3.118	2.501 - 3.735	16.4
Stull Bifluid				
125μ	120.7	0.681	0.597 - 0.765	81.7
250μ	243.6	0.912	0.599 - 1.225	75.6
500μ	495.0	3.274	2.727 - 3.821	12.2
Defoliants pooled				
125μ	123.3	0.730	0.634 - 0.826	80.4
250μ	251.8	1.122	0.806 - 1.438	70.0
500μ	496.6	3.196	2.823 - 3.569	14.3

a. Plants were 9 days old when treated and were harvested 9 days later. Drops were applied with the spinning-cup applicator, and the diameter of the drops was determined concurrently; the number of drops was determined after treatment. The total volume applied to individual plants at all treatments was held constant at about 0.57 μl. All mean values for ORANGE and Stull Bifluid are for 10 plants; thus, pooled values are for 20 plants.

SECTION X

EXPERIMENT 8: THE EFFECTS OF ORANGE AND STULL BIFLUID ON THE GROWTH OF GREEN ASH

1. OBJECTIVE

The purpose of this initial seedling tree experiment was to determine if there was a difference in the growth-inhibition effects of ORANGE and Stull Bifluid on green ash.

2. METHODS

Dormant seedlings of green ash, which had been in cold storage for six months, were potted in vermiculite and grown in the greenhouse for two months prior to application of the defoliants. Thirty trees were selected from this population on the basis of uniformity in size. A completely randomized design was used in which 10 plants each were used for control, ORANGE, and Stull Bifluid.

The RGI syringes were used to apply 1.0 µl per plant as five 0.1-µl drops per leaf over the veins on two leaves of the same whorl. The third whorl from the top of the plant was used on all trees. The plants were harvested 26 days later, and only the new growth was evaluated in terms of height and fresh weight.

3. RESULTS AND DISCUSSION

The results of this experiment are shown in Table XI. There was no significant difference in the response of green ash to ORANGE and Stull Bifluid, either in fresh weight inhibition or in inhibition of stem elongation.

TABLE XI. INHIBITION OF GROWTH IN HEIGHT AND FRESH WEIGHT OF GREEN ASH FROM APPLICATION OF 1.0 MICROLITER OF ORANGE OR STULL BIFLUID[a]

	Height, cm		Fresh weight, g	
Treatment	Mean[b]	% Inhibition	Mean[b]	% Inhibition
Control	40.1	0	10.62	0
ORANGE	30.7	23.4	6.33	40.4
Stull Bifluid	27.9	30.4	4.95	53.4

a. Each defoliant was applied in ten 0.1-µl drops, five drops being applied over the veins on each of two leaves of the same whorl.

b. All data are means for 10 plants.

SECTION XI

EXPERIMENT 9: THE EFFECTS OF ORANGE AND STULL BIFLUID ON THE GROWTH OF SILVER MAPLE

1. OBJECTIVE

The purpose of this seedling tree experiment was to determine if there was a difference in growth-inhibition effects of ORANGE and Stull Bifluid on silver maple.

2. METHODS

Seedlings were grown from seed for approximately two months. Twenty plants were selected for uniformity of height. A completely randomized design was used with 10 plants each for ORANGE and Stull Bifluid. Due to the limited number of uniform plants, controls were not available for this experiment.

The defoliants were applied with the RGI syringe as in the previous experiment, and the plants were harvested 26 days later.

3. RESULTS AND DISCUSSION

The data from this experiment (Table XII) indicated that ORANGE inhibited the growth of silver maple more than did Stull Bifluid, and this difference was significant at the 5% level in the statistical analysis. However, the difference in height, which also favored ORANGE, was not significant. Stull Bifluid not only was less inhibitory to the growth of silver maple than ORANGE, but also was significantly inferior to ORANGE when fresh weight was used as the criterion of effectiveness.

TABLE XII. INHIBITION OF GROWTH IN HEIGHT AND FRESH WEIGHT OF SILVER MAPLE FROM APPLICATION OF 1.0 MICROLITER OF ORANGE OR STULL BIFLUID[a]

Treatment	Height, cm		Fresh weight, g	
	Mean[b]	Difference	Mean[b]	Difference
ORANGE	42.2		14.18	
Stull Bifluid	44.7		17.67	
Stull Bifluid minus ORANGE		2.5		3.49

a. Each defoliant was applied in ten 0.1-μl drops, five drops being applied over the veins on each of two leaves of the same whorl.

b. All data are means for 10 plants.

SECTION XII

EXPERIMENT 10: THE EFFECTS OF ORANGE AND STULL BIFLUID, APPLIED AS 0.02-MICROLITER DROPS ON TEN LEAVES, ON THE GROWTH OF SILVER MAPLE

1. OBJECTIVE

The previous two experiments made comparisons between ORANGE and Stull Bifluid with relatively large drops (0.1 μl) applied to a total of only two leaves per plant. The purpose of this experiment was to determine the effectiveness of the two defoliants applied as very small drops on several leaves.

2. METHODS

Thirty silver maples were selected on the basis of uniformity. A completely randomized design was used with 10 plants each for control, Stull Bifluid, and ORANGE. The defoliants were applied as 50 drops distributed over 10 leaves on each plant. Each treated leaf received five 0.02-μl drops using Hamilton repeating microsyringes. The plants were harvested 23 days after treatment.

3. RESULTS AND DISCUSSION

Based on differences in fresh weight, there was no significant difference between ORANGE and Stull Bifluid (Table XIII). However, ORANGE was better than Stull Bifluid when inhibition of growth in height was used as the criterion of comparison. This difference between Stull Bifluid and ORANGE was significant at the 5% level.

TABLE XIII. INHIBITION OF GROWTH IN HEIGHT AND FRESH WEIGHT OF SILVER MAPLE FROM APPLICATION OF 50 0.02-MICROLITER DROPS OF ORANGE OR STULL BIFLUID[a]

	Height, cm		Fresh weight, g	
Treatment	Mean[b]	% Inhibition	Mean[b]	% Inhibition
Control	62.2	0	10.24	0
ORANGE	33.8	45.7	5.06	50.6
Stull Bifluid	38.2	38.6	4.62	54.9

a. Applied as five drops per leaf on 10 leaves per plant.
b. All data are means of 10 plants.

SECTION XIII

CONCLUSIONS

In seven bean experiments involving many treatment parameters (varieties of beans, size and age of plants, types of leaves treated, number of leaves treated, position of drops on leaves, size of drops, syringe and spinning-cup methods of application, and various environmental conditions at time of application of defoliants), Stull Bifluid was not found to be statistically more effective than ORANGE at the 5% level of probability.

With syringe applications of defoliants, there was a consistent, but not always significant, trend towards the largest number of drops (holding total volume constant) exerting the greatest effect.

The studies with the spinning-cup applicator clearly demonstrated the superiority of applications of many small drops over an equal volume application of larger diameter drops.

On the basis of three experiments with seedling trees, no statistical evidence was obtained to indicate Stull Bifluid was more effective than ORANGE. To the contrary, in two experiments ORANGE was statistically more inhibitory to the growth of trees than was Stull Bifluid. In one instance ORANGE caused a significantly greater reduction of fresh weight than did Stull Bifluid, and in the other instance ORANGE caused a significantly greater reduction of growth in height than did Stull Bifluid.

APPENDIX I

ARRAY OF MICROLITER DOSAGES ON BEAN PLANTS TREATED WITH THE SPINNING-CUP APPLICATOR

TABLE I-1 TREATMENTS WITH ORANGE DROPS AT A NOMINAL SPHERICAL DIAMETER OF 125 MICRONS

Plant no.	No. of drops	Drop size[a]	Total µl
81	414	99	0.207
76	498	112	0.368
77	578	112	0.428
78	604	112	0.447
79	619	112	0.458
70	405	140	0.567
65	439	140	0.615
75	627	126	0.627
68	460	140	0.644
69	466	140	0.652
61	686	126	0.686
80	958	112	0.709
67	597	140	0.836
71	899	126	0.899
74	909	126	0.909
73	965	126	0.965
72	970	126	0.970
62	1010	126	1.010
63	743	140	1.040
64	799	140	1.119
66	1067	140	1.494
Mean	701	127	0.745

a. Determined by Physical Science Division.

TABLE I-2 TREATMENTS WITH ORANGE DROPS AT A NOMINAL SPHERICAL DIAMETER OF 250 MICRONS

Plant no.	No. of drops	Drop size[a]	Total μl
95	57	260	0.524
100	57	260	0.524
88	58	260	0.534
90	59	260	0.543
98	59	260	0.543
82	63	260	0.580
93	64	260	0.589
94	64	260	0.589
96	64	260	0.589
97	65	260	0.598
91	66	260	0.607
84	67	260	0.616
101	67	260	0.616
87	68	260	0.626
89	68	260	0.626
85	69	260	0.635
86	69	260	0.635
83	74	260	0.681
92	86	260	0.791
99	98	260	0.902
Mean	67.1	260.0	0.617

a. Determined by Physical Science Division.

TABLE I-3 TREATMENTS WITH ORANGE DROPS AT A NOMINAL SPHERICAL DIAMETER OF 500 MICRONS

Plant no.	No. of drops	Drop size[a]	Total μl
120	8	498	0.518
107	8	505	0.539
102	9	495	0.572
103	9	495	0.572
104	9	495	0.572
108	9	498	0.582
109	9	498	0.582
110	9	498	0.582
112	9	498	0.582
113	9	498	0.582
115	9	498	0.582
116	9	498	0.582
117	9	498	0.582
118	9	498	0.582
121	9	498	0.582
122	9	502	0.596
123	9	502	0.596
106	9	505	0.607
114	10	498	0.647
119	10	498	0.647
105	10	505	0.674
111	11	498	0.712
Mean	9.1	498.9	0.594

a. Determined by Physical Science Division.

TABLE I-4 TREATMENTS WITH STULL BIFLUID DROPS AT A NOMINAL SPHERICAL DIAMETER OF 125 MICRONS

Plant no.	No. of drops	Drop size[a]	Total μl
141	585	114	0.456
128	486	122	0.462
143	596	114	0.465
142	609	114	0.475
134	508	122	0.483
144	647	114	0.505
146	664	114	0.518
131	589	122	0.560
129	609	122	0.579
133	610	122	0.580
132	626	122	0.595
123	639	122	0.607
140	781	114	0.609
148	843	114	0.658
127	700	122	0.665
145	860	114	0.671
137	639	128	0.703
125	749	122	0.712
136	475	141	0.712
135	517	141	0.776
147	1012	114	0.789
124	835	122	0.793
139	1021	114	0.796
138	735	128	0.808
121	886	122	0.842
130	930	122	0.884
122	1067	122	1.014
126	1081	122	1.027
Mean	725.0	120.9	0.669

a. Determined by Physical Science Division.

TABLE I-5 TREATMENTS WITH STULL BIFLUID DROPS AT A NOMINAL SPHERICAL DIAMETER OF 250 MICRONS

Plant no.	No. of drops	Drop size[a]	Total μl
157	64	236	0.442
158	70	236	0.483
161	70	236	0.483
159	71	236	0.490
162	72	236	0.497
155	78	236	0.538
169	78	236	0.538
151	63	256	0.554
163	81	236	0.559
165	86	236	0.593
150	68	256	0.598
154	57	272	0.598
164	87	236	0.600
156	88	236	0.607
160	93	236	0.642
167	95	236	0.656
149	76	256	0.669
168	98	236	0.676
152	65	272	0.682
166	100	236	0.690
153	66	272	0.693
Mean	77.4	244.0	0.581

a. Determined by Physical Science Division.

TABLE I-6 TREATMENTS WITH STULL BIFLUID DROPS AT A NOMINAL SPHERICAL DIAMETER OF 500 MICRONS

Plant no.	No. of drops	Drop size[a]	Total μl
180	9	482	0.527
181	9	482	0.527
182	9	482	0.527
183	9	482	0.527
185	9	482	0.527
186	9	482	0.527
187	9	482	0.527
188	9	482	0.527
189	9	482	0.527
190	9	482	0.527
191	9	482	0.527
179	10	482	0.586
184	10	482	0.586
171	9	508	0.618
172	9	508	0.618
173	9	508	0.618
174	9	508	0.618
175	9	508	0.618
176	9	508	0.618
177	9	508	0.618
178	9	508	0.618
170	10	508	0.687
Mean	9.1	492.6	0.573

a. Determined by Physical Science Division.

TABLE I-7 FRESH WEIGHT OF BLACK VALENTINE BEANS TREATED WITH ORANGE AND STULL BIFLUID DROPS AT A NOMINAL SPHERICAL DIAMETER OF 125 MICRONS

ORANGE[a/]		Stull Bifluid[b/]	
Plant no.	Weight, g	Plant no.	Weight, g
77	0.57	141	0.55
78	0.61	143	0.74
79	0.88	142	0.72
70	0.55	146	0.92
65	0.75	131	0.63
75	1.14	129	0.79
68	0.99	133	0.62
69	1.19	127	0.68
61	0.40	125	0.64
80	0.71	136	0.52

a. Ten representative plants selected from an original total population (Table I-1) of 21.
b. Ten representative plants selected from an original total population (Table I-4) of 28.

TABLE I-8 FRESH WEIGHT OF BLACK VALENTINE BEANS TREATED WITH ORANGE AND STULL BIFLUID DROPS AT A NOMINAL SPHERICAL DIAMETER OF 250 MICRONS

ORANGE[a/]		Stull Bifluid[b/]	
Plant no.	Weight, g	Plant no.	Weight, g
85	3.02	150	0.97
87	0.52	151	2.00
88	2.31	154	0.60
89	0.86	155	0.63
90	1.66	158	1.05
93	1.33	159	0.98
94	1.53	161	0.62
97	0.72	162	1.09
98	0.60	163	0.53
101	0.77	169	0.65

a. Ten representative plants selected from an original total population (Table I-2) of 20.
b. Ten representative plants selected from an original total population (Table I-5) of 21.

TABLE I-9 FRESH WEIGHT OF BLACK VALENTINE BEANS TREATED WITH ORANGE AND STULL BIFLUID DROPS AT A NOMINAL SPHERICAL DIAMETER OF 500 MICRONS

ORANGE[a]		Stull Bifluid[b]	
Plant no.	Weight, g	Plant no.	Weight, g
102	1.81	171	4.67
103	4.38	173	2.28
104	2.28	177	3.16
106	4.32	178	2.43
112	2.74	181	2.72
113	3.56	185	3.72
115	2.57	187	3.49
118	3.80	189	3.64
119	2.95	190	2.64
122	2.77	175	3.99

a. Ten representative plants selected from an original total population (Table I-3) of 22.
b. Ten representative plants selected from an original total population (Table I-6) of 22.

TABLE I-10 FRESH WEIGHT OF CONTROL BLACK VALENTINE BEANS USED IN ORANGE VERSUS STULL BIFLUID COMPARISONS FOR THREE SPHERICAL DROP SIZES

Plant no.[a]	Weight, g	Plant no.	Weight, g
1	4.01	17	4.16
3	4.40	15	3.69
7	3.69	16	3.33
9	3.12	18	4.47
10	2.69	20	3.51
11	2.84	21	3.48
12	4.19	22	4.32
14	4.02		

a. These 15 plants were selected from the total original control population of 22 plants.

APPENDIX II

RESULTS OF SIX-CROP SCREENING TEST WITH ORANGE, ITS RELATED ESTERS, STULL BIFLUID, AND THE TWO COMPONENTS OF STULL BIFLUID

The seven compounds listed in Table II-1 were evaluated in the Fort Detrick standardized primary screening program, which is planned to discover chemicals having potential as herbicides. A maximum of 24 points is possible in the six-crop test on 7-day-old plants. As this table shows, there is no appreciable difference between Stull Bifluid and ORANGE or the latter's component esters.

TABLE II-1 EVALUATION RATING OF ORANGE, STULL BIFLUID AND OTHER AGENTS IN THE SIX-CROP PRIMARY SCREENING TEST

Fort Detrick No.	Compound	Rating 0.1/1.0 lb/acre
16039	ORANGE (The Dow Chemical Company)	20/20
16540	2,4-D n-Butyl Ester (Hercules Powder Co., Inc.)	20/20
16541	2,4,5-T n-Butyl Ester (Hercules Powder Co., Inc.)	20/20
16540-1	ORANGE (50:50 Mixture 2,4-D + 2,4,5-T esters)	20/20
16556	Bifluid #2	20/20
S-260	Bifluid #1	9/9
---	Stull Bifluid (15 parts 16556 + 1 part S-260)	19/20

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13. ABSTRACT

A comparison of biological effectiveness of Stull Bifluid and ORANGE was made by bioassay techniques using Black Valentine beans, Red Kidney beans, silver maple and green ash as test plants. Single and multiple droplet applications were made at sublethal dosage rates of undiluted herbicide with micrometer syringes and the spinning-cup applicator. Evaluations of growth inhibition of bean plants in terms of fresh weight, dry weight, and/or height showed no difference between Stull Bifluid and ORANGE at the 5% significance level. Variables in seven experiments (bean plants) included size and age of plants, number of treated leaves, position of droplets on leaves, size of drops, and micrometer-syringe versus spinning-cup method of application. Studies with the spinning-cup applicator with comparable total volumes applied in three droplet sizes (125, 250, and 500 μ) showed no difference in response between Stull Bifluid and ORANGE. The smaller droplet sizes gave greater growth inhibition with both materials. Single and multiple droplet applications on seedling trees with the micrometer syringe technique showed ORANGE to be more effective than Stull Bifluid at the 5% significance level in two of three experiments. In the third experiment, there was no significant difference in the two herbicides. In the standard primary screening program with six crop species, additional comparisons among (i) ORANGE, (ii) Stull Bifluid, and (iii) the two Stull Bifluid components, Bifluid #1 and Bifluid #2, at 0.1 and 1.0 pound per acre showed no apparent differences.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Defoliants						
Biological effectiveness						
Stull Bifluid						
ORANGE						
2,4-Dichlorophenoxyacetic acid, _n_-butyl ester						
2,4,5-Trichlorophenoxyacetic acid, _n_-butyl ester						
Phaseolus vulgaris var. Red Kidney						
Phaseolus vulgaris var. Black Valentine						
Acer saccharinum						
Silver maple tree						
Fraxinus pennsylvanica						
Green ash tree						

APPENDIX IV

COMPARATIVE COST ANALYSIS OF THE STULL BIFLUID AND THE AGENT ORANGE DEFOLIANT SYSTEMS

for

U.S. Air Force Armament Laboratory
Bio-Chemical Division
Eglin AFB, Florida

Contract No. F08635-68-C-0015

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BOOZ·ALLEN APPLIED RESEARCH INC.

WASHINGTON

CLEVELAND

CHICAGO

LOS ANGELES

T A B L E   O F   C O N T E N T S

1. BACKGROUND

During the period March 29, 1966 to April 22, 1966, APGC conducted an aerial spray test of the bifluid defoliant developed by the Stull Chemical Company. The results of this test were reported in APGC-TR-67-31, dated March 1967. This report concluded that, while the Stull bifluid did not differ significantly from the defoliant Agent Orange with respect to particle size and effect on certain plants, the bifluid ground deposition level, that is, the concentration of agent within the sprayed area, was consistently higher than that for Orange. The Stull Chemical Company has estimated, based on this conclusion, that the use of their bifluid could result in significant savings to the Government. Subsequently, the Assistant Secretary of the Air Force (R&D) was directed by the Director of Defense Research and Engineering to conduct a conclusive test comparing the two materials.

2. OBJECTIVES

Four test objectives were defined. These were:

(1) Assessment of total recovery of agent,

(2) Measurement of particle size,

(3) Assessment of biological effectiveness,

(4) Appraisal of comparative cost effectiveness.

This report presents an appraisal of comparative cost effectiveness for the A/A45Y-1 system dispersing the Agent Orange compared to the modified A/A45Y-1 system dispersing the Stull bifluid, Bi-Gel.

3. SCOPE

The scope of this report is limited to comparative cost calculations prepared by Booz, Allen Applied Research Inc. based upon deposition data from field trials, and upon specific cost information furnished by the Stull Chemical Company and the U.S. Air Force. Several groups within the Department of Defense are responsible for various other analyses of the results of this test series.

4. APPROACH

The basic approach is:

First, to develop a general cost effectiveness model suitable for comparing Stull bifluid and Orange defoliants. This model, which includes the effects on cost of comparative toxicity and aircraft modifications, is presented in the appenidx to this report, along with a sample calculation using typical values.

Second, to exercise a form of these equations consistent with field test deposition data supplied by ADTC; a toxicity report supplied by the Plant Sciences Laboratory, Fort Detrick; and other criteria developed in the appendix to this report.

The definition of an effective deposition level and a table of comparative cost calculations are presented below.

5. DATA ANALYSIS

Operation Ranch Hand results indicate that Orange (delivered by a C-123 under conditions similar to those of the Eglin tests that produced the data used in this report*) produces a swath width of 80 meters (263 feet), within which the defoliation level is considered sufficient for military purposes.

Analysis of Eglin test results by ADTC personnel have shown that this swath width corresponds to a deposition level of 1.0 gallon per acre. Therefore, this deposition level was defined as the required level of effectiveness in the cost analysis.

Table 1 summarizes the results of all the missions analyzed for this comparison study. The table is based on a deposition level of 1.0 gallon per acre; and contains inwind data for Orange at two average flow rate levels, 131 and 227 gallons per minute, and for bifluid at 129 gallons per minute. These inwind missions were so designed that the disseminating aircraft flew directly into (±20 degrees) the wind. The results presented in the table are based on 17 inwind tests (5 at the higher flow rate for Orange; 6 Orange and 6 bifluid at the lower rate). Table 1 indicates that the average swath width for five inwind Orange missions, delivered at an average 227 gallons per minute flow rate, is 259 feet at 1.0 gallon per acre.

---

* ADTC Technical Report to be issued March 1969.

TABLE 1.

COMPARATIVE COST DATA AT 1.0 GALLON PER ACRE
(130 KIAS, 100' ALTITUDE)

INWIND MISSION

Agent Type	Average Flow Rate (GPM)	Average Swath Width (Feet)	Average Acres Covered by a 1000 Gallon Sortie	Average* Cost/Acre (Dollars)	95% Confidence Interval (Dollars)**
Orange	227	259	346	20.97	19.44-22.50
Orange	131	75	171	45.21	32.24-58.18
Bifluid	129	79	185	45.48	32.49-58.47

* The following method was used to determine the average cost per acre (C/A):

$$C/A = \frac{1}{N} \sum_{i=1}^{N} \frac{\text{cost/mission}}{\text{Acres covered}_i}, \text{ where N = the number of missions.}$$

** The interval between the lower 95% confidence limit ($\bar{x} - 2.571\ s/\sqrt{n}$) and the upper 95% confidence limit ($\bar{x} + 2.571\ s/\sqrt{n}$) where $\bar{x}$ is the average cost, n is the number of missions, and s is the standard deviation of the mission.

The "Average Cost Per Acre" and the "95% Confidence Interval" columns in table 1 indicate that 95% of Orange missions at an average 227 gallons per minute flow rate delivered inwind cost \$19.44 - \$22.50; at an average of 131 gallons per minute, Orange missions cost \$32.24 - \$58.18. The Stull bifluid cost \$32.49 - \$58.47 per mission at the 95% level.

6. CONCLUSIONS

Cost effectiveness (area covered per unit cost at 1.0 gallon per acre) is clearly better when the agent is delivered inwind at approximately 227 gallons per minute than when it is delivered at 131 gallons per minute. This comparison could only be made with the Agent Orange, since the Stull Chemical Company has concluded that, as the system is presently configured, the high r.p.m. rate for a pump capable of achieving the higher flow would have degrading effects on the bifluid.

Both Orange and bifluid produced poor results at the 129-131 gallons per minute rate, when compared to Orange at 227 gallons per minute; neither was statistically superior to the other for inwind missions.

At these lower flow rates, swath widths are narrower compared to Orange at 227 gallons per minute. This fact causes a requirement of approximately three times as many aircraft per mission for bifluid as for Orange to provide equal coverage, thus adding to the higher costs of the bifluid at the lower flow rate of 129 gallons per minute.

APPENDIX

A GENERAL DEFOLIANT COST-EFFECTIVENESS APPROACH

1. INTRODUCTION

This appendix contains a general cost effectiveness model suitable for use in comparing Agent Orange and another defoliant similar to Orange, in this case the Stull Chemical Company's bifluid, Bi-Gel.

This general model is an attempt to calculate defoliant comparative cost effectiveness when various functional relationships are known. Some of these functional relationships are: a ratio of relative toxicities; a ratio of droplet sizes between any two stated ranges; ratios of relative quantities and acreages covered; and, the aircraft operating and modification cost amortized over a given number of years.

2. BASIC DATA

The following data have been furnished by the U.S. Air Force and by the Stull Chemical Company. These represent typical values, and could be subject to change.

1968 cost of Orange	\$7.00/gallon
1968 Orange procurement	4,866,478 gallons
1969 cost of Orange	\$7.08/gallon
1969 Orange projected procurement	5,813,644 gallons
1970 cost of Orange	\$4.88/gallon
Transportation cost of either defoliant	\$0.15/gallon
Gallons of Orange/aircraft sortie	950 gallons
Gallons of all defoliation agents/ aircraft year (1968)	478,000 gallons
Average sorties flown/aircraft day	1.3
Aircraft/defoliant mission	3
Total number of available aircraft	32
Bi-Gel equipment costs	\$1000.00/aircraft

Cost of Bi-Gel

Price for 0-100,000 gallons bifluid defoliant	\$2.60/gallon + cost of the Orange in each gallon
Price for 100,000-500,000 gallons bifluid defoliant	\$2.15/gallon + cost of Orange
Price for over 500,000 gallons bifluid defoliant	\$1.90/gallon + cost of Orange

The following information about mixture ratios of Orange and other materials used to produce Bi-Gel were provided by the Stull Chemical Company.

For 410,158 gallons of Orange sent by the Air Force to the Stull Chemical Company, approximately 500,000 gallons of Bi-Gel defoliant is returned. There is, therefore, approximately 82% Orange in the bifluid, Bi-Gel.

Bi-Gel contains a gelling agent that is added at spray time. The ratio of this additive is 1 part in 16. If X = the total Stull defoliant quantity per sortie, the quantity of the additive for 950 gallons of bifluid preparation is:

$$X = 950 + 1/16X$$

which gives X = 1,013 gallons total defoliant components on board per sortie.
Therefore, the quantity of additive is 1,013 - 950 = 63 gallons.

3. COST EFFECTIVENESS EQUATIONS AND SAMPLE CALCULATIONS

(1) Acres Covered Per Sortie

The general form of the equation for area covered to an effective level is:

$$C = \frac{(\text{effective swath width, ft.})(\text{delivered defoliant, gal.})(\text{AC speed, ft./min.})}{(\text{dissemination rate, gal./min.})(43560,\ \text{ft}^2/\text{acre})}$$

(2) Defoliant and Other Costs

The quantity of defoliant delivered by Orange and bifluid missions and, therefore, defoliant costs, are determined two ways in this report. First, calculations are made assuming 950 gallons of defoliant for an Orange mission and 950 + 63 = 1,013 gallons of Bi-Gel for a bi-fluid mission. The 63 gallons represents the gelling agent added at spray time. In addition, calculations are made assuming 1,000 gallons of defoliant delivered for a sortie of either defoliant. One thousand gallons per sortie is the actual tank capacity.

Actual cost figures are presented below:

1. Orange Costs Per Sortie

$7.23/gallon Orange = ($7.08 + $0.15)

$6,868.50 per aircraft sortie = ($7.23 per gallon) (950.0 gallons per sortie)

$7,230.00 per aircraft sortie = ($7.23 per gallon) (1,000 gallons per sortie)

2. Bi-Gel Costs Per Sortie

$5.80 - Orange costs in one gallon of Bi-Gel = ($7.08)(0.82)

$1.90 - charge for gelling and other agents, and mixing costs per gallon of Bi-Gel assuming at least 500,000 gallons are procured.

$0.15 - transportation costs per gallon.

$7.85 - total cost per gallon of Bi-Gel defoliant.

$7,952.05 per aircraft sortie = ($7.85 per gallon) (1,013 gallons/sortie)

$7,850.00 per aircraft sortie = ($7.85 per gallon) (1,000 gallons per sortie)

3. Aircraft Amortization

Orange sorties per aircraft day (based on 1968 data):

$$\frac{(4{,}866{,}478 \text{ gallons Orange/year})(1.3 \text{ sorties/AC day})}{(478{,}000 \text{ gallons of all agents/AC year})(32 \text{ aircraft})}$$

= 0.4136 Orange sorties/aircraft day

4. Special Equipment Costs for Bi-Gel

(Based on 1969 projected data.)

$$\frac{(\$1,000.00/\text{aircraft})(32 \text{ aircraft})}{(5,813,644 \text{ gallon/year})(X \text{ years amortization})} = \frac{\$0.0055/\text{gal}}{X}$$

$$\frac{(\$0.0055/\text{gal.})(1013 \text{ gal./sortie})}{X} = \frac{\$5.5715}{X}$$

$$= \frac{\$5.5715/\text{sortie}}{X}$$

5. Aircraft Operating Costs

Aircraft operating cost/sortie (AC/S) =

$$(\text{aircraft cost/day}) \frac{(\text{Orange sorties/day})}{(\text{total sorties/day})}$$

If we assume constant sorties/day, then:

$$AC/S = (\text{aircraft cost/day}) \frac{(.4136)}{(1.3)} = .318A \quad (A - \text{aircraft cost/day})$$

(3) Cost Effectiveness Equation

Cost Per Acre:

Orange: $(.318A + \$6,868.50)/C_o$

Bi-Gel: $(.318A + \$7,952.05 + \$5.57)/C_b$

where:

A = aircraft cost/day

C_o = Orange effective area coverage, and

C_b = Bi-Gel effective area coverage

\$5.57 = special equipment costs for Bi-Gel amortized over 1 year

$$C_b = \frac{(\text{toxicity Bi-Gel})}{(\text{toxicity Orange})} \; f \; \frac{(\%\ 100\text{-}500 \text{ for Bi-Gel})}{(\%\ 100\text{-}500 \text{ for Orange})} \; C_o$$

where: f is a functional relationship between the effective area coverage of an Orange mission (C_o) and the area coverage which would have been produced if Bi-Gel had been used.

This relationship assumes that the percentage of droplets between 100-500 bears a direct linear relationship to the quantity of recoverable defoliant. This is not assumed in the data analysis section of this report, but it is included here for completeness.

(4) Reduction of the general model for the data analysis section of this report:

Since the toxicity ratio actually = 1.0,* and test data on quantity is available, this general equation can be reduced to:

Orange: $(.318A + \$6,868.50)/C_{om}$

Bi-Gel: $(318A + \$7,952.05 + \$5.57)/C_{bm}$

where: C_{om} = Orange effective area coverage, measured from test data

C_{bm} = Bi-Gel effective area coverage, measured from test data

Further, since the ratio of defoliant sorties to the total sorties a spray plane would conduct per day, and the years for which to amortize costs affects both defoliants nearly the same, this equation can further be reduced to:

Orange (1000 gal. sortie): $\$7,230.00/C_{om}$

Bi-Gel (1000 gal. sortie): $\$7,850.00/C_{bm}$

where: 1000 gallons has been selected as a theoretically deliverable quantity per sortie for each defoliant. The use of this common quantity makes cost comparison of the two agents less dependent on tank size differences.

* "Bifluid was not found to be statistically more effective than Orange at the 5% level of probability," AF MPR PG 8-72, Plant Sciences Laboratories, Dept. of the Army, Fort Detrick, Maryland.

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APPENDIX V

Spread Factor Study of Drops of Orange and Stull Bifluid Defoliants on Kromekote Cards and Plant Leaves

Walton R. Wolf
Physical Science Division
Fort Detrick

TECHNICAL REPORT AFATL-TR-68-123

OCTOBER 1968

AIR FORCE ARMAMENT LABORATORY
AIR FORCE SYSTEMS COMMAND
EGLIN AIR FORCE BASE, FLORIDA

SPREAD FACTOR STUDY

OF DROPS OF ORANGE AND STULL BIFLUID DEFOLIANTS

ON KROMEKOTE CARDS AND PLANT LEAVES

Walton R. Wolf

FOREWORD

The research reported herein was conducted under U.S. Air Force Project Number 5172. The work was conducted by the Physical Science Division, Department of the Army, Fort Detrick, Frederick, Maryland, 21701, during the period 11 June through 12 September 1968. The work was funded via U.S. Air Force Military Interdepartmental Purchase Request PG-8-72, and Mr. Marshall Solomon (AFATL/ATCB), Eglin Air Force Base, Florida, was the program monitor.

The author is indebted to Mr. Robert A. Boulster and Mr. Richard H. Zile who assisted in all phases of this study, including laboratory work, data collection and data assembly. The author is also indebted to Mr. George W. Trout, Jr. who was responsible for the statistical treatment of the data.

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JOHN E. HICKS, Colonel, USAF
Chief, Biological-Chemical Division

ABSTRACT

A spread factor calibration study was performed to correlate the spherical drop sizes of both ORANGE and Stull Bifluid defoliants with the spot sizes they produced by absorption and spreading on Kromekote cards. The results of this study show that the spread factor gradually increases for both defoliants with increasing drop size. Statistical treatment of the data was performed to obtain best-fit line plots for both materials. Best-fit line equations were statistically different for ORANGE and Stull Bifluid data. These differences may be small enough to be of little practical significance. Spread factor studies were performed employing mixtures of Bifluid #2 and Bifluid #1 at ratios of both 13:1 and 17:1. The spread factors for these mixtures were not significantly different from that for the standard 15:1 Stull Bifluid mixture. A study was also made to compare the spread of ORANGE and Stull Bifluid drops on leaves of various plant species. The results of this study were highly variable but indicated that, on the average, Stull Bifluid drops spread slightly more than ORANGE drops. This small average difference in drop spread may not be of practical significance.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

SECTION I

INTRODUCTION

The main objective of this effort was to correlate the spherical diameter of drops of ORANGE and Stull Bifluid defoliant formulations with the size of the spots produced by these drops on plain white Kromekote cards. Subsidiary studies included spread factor determinations for both defoliants on leaves of various plant species and spread factor determinations of Stull Bifluid formulations deviating from the recommended 15:1 ratio.

This study involved the development of new techniques to determine spread factors over an extended range of drop sizes heretofore not attempted and new techniques for spherical drop size measurement. Accordingly, all aspects of physical spread determinations have been examined in accordance with MIPR PG-8-72 and related written communications.

SECTION II

MATERIALS

Throughout this report, the two ingredients that form the Stull Chemical Co. formulation when properly mixed have been identified as Bifluid #1 and Bifluid #2. These descriptors are equivalent to the terms Bigel #1 and Bigel #2, which frequently appear in other documents concerning the Stull formulation. The admixture of Bifluids #2 and #1 in the 15:1 ratio is the standard recommended mixture and is referred to in this report simply as Stull Bifluid. Bifluid mixtures at ratios deviating from the standard, which were included in this study, were not considered Stull Bifluid in the strictest sense, and the data for them were not included in the drop-card spot regression analysis. Bifluid #1, Bifluid #2, Automate Red B dye (Ethyl Corp.), and Kromekote cards were supplied by Eglin AFB. ORANGE defoliant (50% n-butyl ester of 2,4-D + 50% n-butyl ester of 2,4,5-T) and test plants were supplied by Plant Sciences Laboratories, Fort Detrick.

Automate Red B dye was added to both ORANGE and Bifluid #2 to yield a 1% concentration (w/w). Standard Stull Bifluid was prepared by the addition of 15 parts Bifluid #2 to 1 part Bifluid #1, except in those nonstandard studies with mixing ratios of 13 to 1 and 17 to 1. Bifluid mixtures were prepared on a volume/volume basis.

Measurements recorded in Table I show that both shear and age affect the viscosity of the Stull Bifluid. The viscosity versus age effect made it necessary to repeatedly prepare fresh samples in order that laboratory tests approached field conditions. Table II shows the viscosities of ORANGE and Bifluids #1 and #2. The admixture of the Stull additives and ORANGE that constitutes Bifluid #2 had a reduced viscosity when compared to ORANGE alone. Bifluids #1 and #2 became non-Newtonian only after their admixture. The densities of the various materials employed in this study are given in Table III.

TABLE I. VISCOSITY VERSUS TIME FOR STANDARD 15:1 STULL BIFLUID AT 25 C

Spindle rpm[a/]	Viscosity, cps	Time, seconds
6	3760	180
12	2660	230
30	1260	350
6	2160	1500
12	1460	1550
30	1040	1650
6	1960	5800
12	1360	5900
30	940	6300

a. All tests were run on Brookfield Spindle No. 4.

TABLE II. VISCOSITIES OF ORANGE, BIFLUID #1, AND BIFLUID #2 AT 25 C

Material	Brookfield spindle no.	Spindle rpm	Viscosity, cps
ORANGE	2	30	43.0
	2	60	42.5
	1	30	42.4
	1	60	42.2
Bifluid #1	1	30	5.0
	1	60	5.5
Bifluid #2	1	30	34.0
	1	60	33.6

TABLE III. DENSITIES OF ORANGE, BIFLUID #1, BIFLUID #2 AND STANDARD 15:1 STULL BIFLUID AT 25 C

Material	Density, grams/ml
ORANGE	1.271
Bifluid #1	0.8379
Bifluid #2	1.2344
Stull Bifluid	1.215

SECTION III

METHODS

1. DROP GENERATION AND COLLECTION

The spinning cup drop generator was employed for all trials except the Kromekote card spread factor studies for ORANGE. The electromechanical vibrating reed[1] was employed for small ORANGE droplet production, and the mechanical reed for large ORANGE drop production, because their aimability of droplets provided for more convenient sampling procedures. The vibrating reed proved unsuitable for droplet production with the viscous Stull Bifluid. The spinning cup drop generator as described elsewhere[2] was only slightly modified by increasing the number of orifices to include all needle gauge stock from 19 through 37 gauge in an attempt to increase the drop size range requested in this study. However, the needle sizes smaller than 32 gauge (4-mil orifice) were impractical because they clogged. Two such cups were fabricated and employed in this study. Production of fine uniform droplets of Stull Bifluid was a special problem; it was partly solved by fabricating a third cup in which the hypodermic-needle orifices routinely employed were replaced by a 1-mil platinum electron microscope aperture. This aperture was mounted in a suitable housing and affixed to the spinning cup's maximum diameter. A balancing weight was placed on the opposite side of the cup to minimize vibration at the high rotational speeds required for small droplet production. These higher speeds were achieved with appropriately mounted Virtis type "23" and "45" homogenizer motors. Maximum no-load speeds for these motors are 23,000 and 45,000 rpm, respectively. The combined use of the microscope aperture and the smallest practical hypodermic needle (32 gauge) permitted the production of uniform droplets as small as 30 microns in diameter.

For the production of larger uniform drops (greater than 100 microns), the cups were mounted on the high-speed shafts (0 to 5000 rpm) of GT-21 laboratory mixer motors (G.H. Heller Co.), and the cups' rotational speeds were varied by the companion GT-21 motor controllers.

In the previous study[2] of Stull Bifluid, a twin-duct fluid-metering system was employed to simulate the mixing of Bifluids #1 and #2 at the spray nozzles under actual field conditions. This method was not employed in this study because, under current field trial conditions, the mixing of Bifluids #1 and #2 occurs at the pumps in the aircraft and thus may occur at some time and distance prior to the conversion of the bulk mix into spray drops. In this study, 10-ml and 2-ml B-D Cornwall continuous pipetting outfits were employed to dispense 7.5 ml of Bifluid #2 and 0.5 ml of Bifluid #1, respectively, in a common container. The ingredients were then manually stirred until a smooth viscous mix was obtained, which was immediately transferred to the spinning cup. This arrangement permitted the repeated preparation of small fresh quantities of the standard 15:1 Stull Bifluid throughout the course of the study. The only modification required in the continuous pipetters was replacement of the Buna-N valves with Teflon valves because the Buna-N valves were swelled by Bifluid #2.

Sheet metal shrouds with adjustable slot-width openings on their sides were placed around the cups to (i) limit the arc of the droplet free-fall spray and (ii) protect the operator against the hazards of disengagement of the spinning cup or its components. The physical arrangement of the apparatus for drop production and collection was basically the same as previously described.[1,2]

2. THE SAMPLERS

a. Kromekote Card Spot Sampler

Plain, white, 5- by 7-inch Kromekote cards were used throughout this study. These cards were used as received for all spot sample collection studies employing the spinning cup generator and subsequently were cut into 1- by 3-inch sections for convenient microscopic measurement. In studies employing the electromechanical and mechanical reed, the cards were pre-cut to 1 by 3 inches. These cards readily accommodate ORANGE and Stull Bifluid drops, both of which are absorbed into the cards and spread by diffusion to form spots of roughly circular geometry. Typical drop spot patterns on these cards are shown in other reports.[2,3] Although an intense center spot surrounded by a lighter outer spot is characteristic of the larger Stull Bifluid spots, the center spot was not observed in most cases for outer spots less than 500 μ in diameter.

b. Spherical Drop Sampler

The gelatin-Methocel method previously employed for spherical drop measurement was abandoned early in this study when it was discovered that glycerin was a more convenient drop-collecting fluid. Cells were fabricated by cementing 1- by 3-inch microscope slides to the sides of a U-shaped Lucite block measuring ½ inch thick by 1 inch high (at the arms of the U) by 3 inches long. The cells thus constructed measured ½ inch wide by 1 inch deep by 3 inches in length. In later studies, the depth of the reservoir of the cell was increased from ½ inch to about 1½ inches by employing 2- by 3-inch microscope slides cemented to ½-inch-thick U-shaped Lucite blocks.

Cells were prepared as follows for ORANGE droplet collection: 100% concentrated USP grade glycerin was added until it filled the cell to within a few millimeters of its top surface. Distilled water was then carefully overlayed on the glycerin surface until the cell was brim full. Glass slides (½ by 3 inches) were coated with a mixture of 2% polyvinyl alcohol (Elvanol 51-05) and 2% wetting agent (Kodak Photo-Flo) and allowed to air dry to form a continuous water-soluble film. The wetting agent insured a uniform coating over the slide. Polyvinyl alcohol was substituted for the previously employed Methocel for coating slides when it was discovered that Methocel was not compatible with glycerin. Apparently, an insoluble capsular film of methylcelluiose forms at the drop-glycerin interface and inhibits the drop from completely collapsing into spherical symmetry. Droplets of ORANGE were collected on the film-coated slides and immediately inverted over the filled cells. The water in the cell contacts and dissolves the film and releases the sessile drops, which rapidly settle to the sharp glycerin-water interface. The drops penetrate the interface and become located in the viscous glycerin, where they slowly descend for convenient microscopic measurement. Aside from clarity and immiscibility with ORANGE drops, glycerin proved to be unique because its high viscosity (945 cps at 25 C) and its density match with ORANGE. The density of ORANGE was determined to be 1.271 at 25 C, whereas glycerin has a slightly lower density of 1.262 at 25 C.

A different technique, to be described later, was employed for the determination of spherical drop diameter of small ORANGE droplets.

The viscous nature of the largest Stull Bifluid drops introduced new problems in spherical drop size determination. The mixture of the Stull additives (including Automate Red B dye) with ORANGE to formulate Bifluid #2 reduced the density to 1.21 at 25 C. Dilution of the glycerin with water to about 96% glycerin (w/w) yields a medium at 25 C that has a density of 1.201 and a viscosity of 435 cps. Such a medium would have been quite adequate were it not for that fact that both the Stull Bifluid drops and the glycerin solution resist the collapse of the sessile drops (on the coated slides) into a spherically symmetric state in the medium. Under such conditions, it was observed that the collapse resistance increased with drop size to an extent that spherical measurements were delayed beyond a practical time limit. To circumvent this problem, an increasing viscous gradient was established from top to bottom of the cells so that the droplets experienced a gradual reduction in settling velocity and thus had sufficient time to achieve spherical symmetry before entering a highly viscous environment. During the course of this study, the gradient was established in numerous ways but always in such a manner that no sharp gradients occurred that were likely to cause optical distortion of the drops due to changes in refractive index. Typical methods employed to form the gradient consisted of (i) overlaying cells half filled with pure glycerin with water and permitting slow diffusion to occur, (ii) applying layer upon layer of solutions of decreasing glycerin content, or (iii) teasing the glycerin-water interface to assist the slower diffusion process in establishing the viscous gradient. In all other respects, collection of Stull Bifluid drops was identical to that described for ORANGE drops.

For small ORANGE droplets (< 100 micron spherical diameter), the glycerin technique previously described was impractical because of the extremely slow rate at which the small droplets penetrated the water-glycerin interface. The glycerin gradient cell employed for Stull Bifluid drops was not perfected at the time this portion of the study was conducted, although it later proved suitable for use with small ORANGE droplets in the plant leaf studies. For these reasons, a different medium consisting of either 25 or 27.5% $CaCl_2$ (w/v) replaced the medium in the cell. The densities of these salt solutions approach that of the ORANGE droplets but have much lower viscosities than the glycerin medium. Thus, the viscous interface was eliminated, and the close density match alone sufficed to reduce the settling velocity for very small drops. The chief disadvantage of the calcium chloride medium was that the slightest vibration of the cell caused the drops to vibrate, making the task of drop measurement quite tedious. The various media employed in the cells for spherical drop measurement were checked for immiscibility with both ORANGE and Stull Bifluid drops. No change in drop size could be observed for either material for time periods as great as 1½ hours and for various drop sizes covering the size range of interest.

c. Plant Leaf Samplers

Both herbaceous and nonherbaceous (woody) plants were selected for this study. Pertinent information regarding these plants is given in Table IV. All plants studied were greenhouse grown. The smaller leaves at the top of the plant were removed to expose leaves of sufficient area for drop collection. On each plant, one or more of the uppermost plant leaves was exposed to drops of Stull Bifluid and other top leaves on the same plant were exposed to ORANGE drops comparable in size to the Stull Bifluid drops. All other foliage on the plant under test was suitably masked to avoid drop contact during exposure.

TABLE IV. TYPES AND CHARACTERISTICS OF PLANTS EMPLOYED IN LEAF SPREAD-FACTOR STUDIES

Common name	Botanical name	Herbaceous	Woody	Deciduous	Evergreen	Dicot	Age
Red Kidney Bean	_Phaseolus vulgaris_ var Red Kidney	X				X	2 weeks
Black Valentine Bean	_Phaseolus vulgaris_ var Black Valentine	X				X	3 weeks
Silver Maple	_Acer saccharinum_		X	X			2½ months
Green Ash	_Fraxinus pennsylvanica_		X	X			1 year
Dwarf Brush Cherry	_Eugenia myrtifolia globolus_		X		X		1 year
Live Oak	_Quercus virginiana_		X		X		1 year

3. MICROSCOPIC MEASUREMENTS

Ordinary light microscopes were employed for all card spot measurements. With few exceptions, Filar type movable hairline eyepieces were employed in combination with 2X objectives. The same eyepiece objective combinations were employed for all plant spot measurements. However, the bulkiness of the plants required an optical arrangement for convenient measurement of leaf spots. Such an arrangement was devised by mounting microscope barrel assemblies on heavy tripods equipped with racks and pinions for height adjustment. A Cooke-A.E.I. image-splitting eyepiece was employed in combination with 5X and 10X objectives on standard light microscopes for all spherical drop measurements. This eyepiece proved especially useful in ascertaining when Stull Bifluid drops attained spherical symmetry.

SECTION IV

RESULTS

1. SPREAD FACTOR STUDIES ON KROMEKOTE CARDS

The raw data analysis for ORANGE defoliant drops and their corresponding card spots is given in Appendix I. With few exceptions, ten spherical drops and ten card spots were routinely measured for each sample collected. In contrast to gelled Stull Bifluid, the ORANGE droplets readily collapsed into perfect spheres, and the need for two measurements on each drop was not required. The nonsymmetric shape of the card spots warranted two measurements at 90° to one another. In most cases, overnight absorption of the ORANGE drop into the card sufficed to yield an equilibrated card spot size. A few samples in the larger card spot size range required 48 hours to achieve constancy in the card spot size. In Appendix I, the samples are listed in order of increasing mean spherical drop size.

The raw data analysis for Stull Bifluid drops and their corresponding card spots are given in Appendix II. For this material, two measurements 90° apart were made on both spherical drops and card spots. Despite best efforts, complete collapse of the drops into spherical symmetric geometry was not always completely achieved. Deviations from spherical shape most frequently occurred in the larger drop sizes. These deviations led to an early decision that more data might be needed for the Stull Bifluid data analysis than for the ORANGE analysis and, consequently, partly explains the more detailed data collection.

Tables V and VI summarize the raw data for ORANGE and Stull Bifluid, respectively. An attempt was made to obtain a sufficient amount of data to provide a spherical drop increment of 50 microns or less over the requested range of interest. The last column of Tables V and VI show, with few exceptions, that this was accomplished within the card spot size range of most interest. A contributing factor to the more detailed spread factor data for Stull Bifluid drops is their extended upper-drop-size limit as compared with that of ORANGE defoliant. Although data on card spots larger than 5,000 microns was not requested, it was included in the event that the viscous nature of the Stull Bifluid might shift the spray spectrum to sizes larger than would be anticipated for ORANGE defoliant sprays. Table VI also includes measurements on the center card spot as well as the outer card spot formed from drops of Stull Bifluid. A trend is clearly shown in that the experimental outer card spot spread factor increases with increasing spherical drop size. The center card spot appears to fluctuate slightly around a mean spread factor of 1.7 and never deviates more than 0.4 from this mean. For some unexplained reason, the center card spot was either ill-defined or absent in a number of the smaller card spot samples.

TABLE V. SUMMARY OF ORANGE DEFOLIANT RAW DATA ANALYSIS

Sample number	Spherical drop size, microns	Card-spot size, microns	Experimental spread factor	Spherical drop increment
1	31.2	105.4	3.3782	3.9
2	35.1	116.6	3.3219	1.5
3	36.6	130.1	3.5546	9.7
4	46.3	169.2	3.6544	5.9
5	52.2	188.3	3.6072	24.8
6	77.0	323.5	4.2012	1.4
7	78.4	323.5	4.1262	2.4
8	80.8	309.1	3.8254	0
9	80.8	357.6	4.4257	8.3
10	89.1	448.0	5.0280	42.2
11	131.3	711.4	5.4181	10.7
12	142.0	705.1	4.9654	51.5
13	193.5	1201.4	6.2087	19.9
14	213.4	1369.2	6.4161	19.7
15	233.1	1471.3	6.3376	6.3
16	239.4	1384.6	5.7836	21.4
17	260.8	1775.6	6.8082	28.6
18	289.4	1917.9	6.6271	11.1
19	300.5	2094.2	6.9690	31.9
20	332.4	2107.2	6.3393	23.8
21	356.2	2259.7	6.3439	6.1
22	362.3	2245.2	6.1970	16.8
23	379.1	2482.0	6.5470	29.2
24	408.3	2826.6	6.9228	17.2
25	425.5	2915.1	6.8509	0.3
26	425.8	3108.2	7.2996	3.5
27	429.3	3081.6	7.1781	36.5
28	465.8	3652.7	7.8417	7.8
29	473.6	3486.2	7.3610	40.7
30	514.3	3816.8	7.4213	49.8
31	564.1	3998.1	7.0875	7.4
32	571.5	4160.8	7.2804	2.5
33	574.0	3964.1	6.9060	18.2
34	592.2	4704.4	7.9439	40.4
35	632.6	4837.0	7.6462	23.1
36	655.7	5044.6	7.6934	39.4
37	695.1	5136.9	7.3901	14.7
38	709.8	5483.0	7.7247	7.7
39	717.5	5706.0	7.9526	12.3
40	729.8	5652.2	7.7448	---

TABLE VI. SUMMARY OF STULL BIFLUID DEFOLIANT RAW DATA ANALYSIS

Sample number	Diameter, microns: Spherical drop	Diameter, microns: Card spot Outer	Diameter, microns: Card spot Center	Spot spread factors: Outer	Spot spread factors: Center	Spherical drop increment
1	31.8	100.2	---a/	3.1509	---	3.9
2	35.7	101.2	---	2.8347	---	3.6
3	39.3	118.4	---	3.0127	---	0.7
4	40.0	118.9	65.3	2.9725	1.6325	3.9
5	43.9	151.5	---	3.4510	---	0.1
6	44.0	144.1	91.8	3.2750	2.0863	8.7
7	52.7	186.0	---	3.5294	---	9.3
8	62.0	198.6	84.4	3.2032	1.3612	1.2
9	63.2	251.3	---	3.9762	---	10.5
10	73.7	280.2	---	3.8018	---	1.1
11	74.8	288.1	---	3.8516	---	5.2
12	80.0	352.9	---	4.4112	---	4.6
13	84.6	347.8	133.8	4.111	1.5815	3.2
14	87.8	354.3	---	4.0353	---	15.9
15	103.7	428.0	152.4	4.1272	1.4696	0.7
16	104.4	461.5	184.1	4.4204	1.7634	3.7
17	108.1	461.1	---	4.2654	---	0.7
18	108.8	496.0	---	4.5588	---	9.0
19	117.8	583.2	215.9	4.9507	1.8327	26.6
20	144.4	744.1	262.5	5.1530	1.8178	27.3
21	171.7	934.3	317.5	5.4414	1.8491	15.2
22	186.9	1091.8	330.1	5.8416	1.7661	1.0
23	187.9	1177.6	338.5	6.2671	1.8014	42.1
24	230.0	1409.3	397.7	6.1273	1.7291	19.2
25	249.2	1543.6	392.5	6.1942	1.5750	0.6
26	249.8	1486.7	483.9	5.9515	1.9371	0.7
27	250.5	1528.2	473.2	6.1005	1.8890	18.2
28	268.7	1642.4	418.2	6.1123	1.5563	4.4
29	273.1	1730.5	461.5	6.3365	1.6898	4.7
30	277.8	1759.9	421.4	6.3351	1.5169	23.9
31	301.7	1924.5	468.5	6.3788	1.5528	2.0
32	303.7	2007.5	486.2	6.6101	1.6009	1.4
33	305.1	1970.6	495.1	6.4588	1.6227	5.0
34	310.1	1742.7	467.6	5.6198	1.5079	7.7
35	317.8	1983.7	469.0	6.2419	1.4757	1.6
36	319.4	1994.4	508.2	6.2442	1.5911	26.0
37	345.4	2329.1	611.2	6.7431	1.7695	4.9
38	350.3	2270.9	582.3	6.4827	1.6622	9.6
39	359.9	2388.8	577.2	6.6373	1.6037	24.9
40	384.8	2537.1	645.7	6.5932	1.6780	27.7
41	412.5	2782.3	754.8	6.7449	1.8298	19.1
42	431.6	2906.3	758.5	6.7337	1.7574	10.5
43	442.1	2886.2	738.9	6.5283	1.6713	3.4
44	445.3	2952.4	774.8	6.6271	1.7391	0.7
45	446.2	3176.2	859.2	7.1183	1.9255	42.4
46	488.6	3373.0	787.4	6.9033	1.6115	2.3
47	490.9	3359.0	831.7	6.8425	1.6942	53.2
48	544.1	3844.3	950.1	7.0654	1.7461	7.8
49	551.9	4255.5	948.7	7.7106	1.7189	9.8
50	561.7	4256.4	1042.9	7.5777	1.8566	9.7
51	571.4	4083.0	916.1	7.1456	1.6032	9.1
52	580.5	4553.8	976.2	7.8446	1.6816	16.3
53	596.8	4257.8	1124.0	7.1343	1.8833	1.0
54	597.8	4198.6	1038.2	7.0234	1.7367	5.9
55	603.7	4607.5	959.0	7.6321	1.5885	35.2
56	638.9	4913.9	1015.1	7.6911	1.5888	31.1
57	670.0	4867.8	1184.3	7.2653	1.7676	45.4
58	715.4	5582.9	1245.8	7.8039	1.7414	88.1
59	803.5	6398.1	1399.6	7.9627	1.7418	30.8
60	834.3	6621.1	1491.9	7.9361	1.7882	26.3
61	860.6	7436.2	1622.6	8.6407	1.8854	---

a. Center card spot either ill-defined or absent.

ORANGE and Stull Bifluid data were fitted with the best linear and curvilinear expressions by least squares regression analysis. Polynomials of increasing degree were fitted until two consecutive terms were observed to be statistically insignificant or until the standard error of estimate increased rather than decreased. Terms higher than the second degree were always insignificant. Expressions relating the logarithm of the spherical diameter to the logarithm of the card spot diameter were also fitted to the data with good success.

If the two sets of data proved to be statistically the same, then a best fitting line could be determined that would adequately describe both sets with one expression. Such was not the case because, in all the determined expressions, one or more parameters proved to be significantly different or only marginally significant.

The best-fitting line was judged "best fitting" on the basis of several criteria. The first of these is the coefficient of determination, r^2, or the percentage of the variance in spherical diameter data removed by the regression line. To obtain a best-fitting line, r^2 should approach 100%. Linear lines through the data always exceeded 95%, and the best-fitting lines exceeded 99%. The value of this coefficient always increases with the addition of higher polynomial terms, so that, of itself, this coefficient is not an adequate judge of a best-fitting line. The second criterion used was the F test for significance of the fit. In general, the higher the F value the more significant the fit becomes. All determined expressions had highly significant F values for the linear term; the quadratic terms were also highly significant, but addition of cubic and quartic terms proved insignificant. A third criterion used was the value of s, the standard error of estimate. Mathematically, s is the square root of the sum of squares of deviations from the regression line divided by the degrees of freedom. Ideally, the error term should be as low as possible. Invariably, the quadratic expression reduced the value of s over that of the linear expression, while the cubic and quartic expression increased the value of s over that of the quadratic expression.

Tables VII and VIII list the best-fitting quadratic and log-log expressions for both the ORANGE and Stull Bifluid data, respectively. In addition, these tables include the values of r^2, F, and s for each equation. Where applicable, the F test for significance of fit is broken down into F1 and F2 terms for the significance of the linear and quadratic terms, respectively. The tables also include the standard deviation of the parameters of the expressions along with their 95 and 99% confidence limits.

Because the quadratic and log-log expressions are practically equal in their significance of fitting the data for a given material, it is difficult to recommend which expression should be used. Further laboratory experimentation to obtain both smaller and larger spherical diameters might lead to a preference of one over the other.

TABLE VII. ORANGE DEFOLIANT: STATISTICAL LINE FITS AND THEIR CHARACTERISTICS

Quadratic		Log-Log
$SDD^{a/} = 26.22 + 0.14785\ (CSD)^{b/} - 4.42 \times 10^{-6}\ (CSD)^2$		$\text{Log SDD} = -0.079619 + 0.779948\ \text{Log}\ (CSD)$
Coefficient of determination (r^2)	0.9957	0.9954
F test for significance		
F1	8530	8230
F2	26	---
Standard error of estimate(s)	15.23	0.02879
Std. dev. of intercept	5.24	0.027532
Std. dev. of slope	0.00483	0.008596
Std. dev. of quad. term	8.67×10^{-8}	
95% Conf. range on intercept	15.62 to 36.81	-0.134407 to -0.024831
99% Conf. range on intercept	12.05 to 40.39	-0.154065 to 0.005173
95% Conf. range on slope	0.13808 to 0.15762	0.762575 to 0.797322
99% Conf. range on slope	0.13478 to 0.16092	0.756704 to 0.803193
95% Conf. range on quadratic term x 10^6	-6.18 to -2.67	---
99% Conf. range on quadratic term x 10^6	-6.77 to -2.08	---

a. SDD = spherical drop diameter.
b. CSD = card spot diameter.

TABLE VIII. STULL BIFLUID DEFOLIANT: STATISTICAL LINE FITS AND THEIR CHARACTERISTICS

Quadratic		Log-Log
$SDD^{a/} = 28.46 + 0.15303\ (CSD)^{b/} - 5.30 \times 10^{-6}\ (CSD)^2$		$\text{Log SDD} = -0.001484 + 0.759132\ \text{Log (CSD)}$
Coefficient of determination (r^2)	0.9975	0.9977
F test for significance		
F1	22,600	25,900
F2	190	---
Standard error of estimate(s)	11.72	0.01964
Std. dev. of intercept	2.95	0.002558
Std. dev. of slope	0.00244	0.004713
Std. dev. of quad. term	3.88×10^{-8}	
95% Conf. range on intercept	22.56 to 34.37	-0.006575 to 0.003606
99% Conf. range on intercept	20.61 to 36.32	-0.007368 to 0.004400
95% Conf. range on slope	0.14815 to 0.15791	0.749753 to 0.768510
99% Conf. range on slope	0.14654 to 0.15952	0.748292 to 0.769971
95% Conf. range on quadratic term x 10^6	-6.08 to -4.52	---
99% Conf. range on quadratic term x 10^6	-6.33 to -4.26	---

a. SDD = spherical drop diameter.
b. CSD = card spot diameter.

Figures 1 through 4 are plots of the experimental data extracted from Tables V and VI. The plots are intended to present a qualitative picture of the data obtained over the card-spot size range studied. The multiplicity of experimental data sometimes precluded illustrating each discrete point on a graphical plot of the size used. Best-fit lines are drawn through the data to visually depict the goodness of fit. Employing the equations given in Tables VII and VIII, spherical diameters were calculated for arbitrarily selected increments of card spot diameter over the card-spot size range of interest. These values, along with the calculated spread factors, are presented in Tables IX and X for ORANGE and Stull Bifluid drops, respectively.

2. THE EFFECT OF STULL BIFLUID MIXING RATIO ON SPREAD FACTOR

In operational practice, the mixing ratio of Bifluids #2 and #1 can vary from 13:1 to 17:1, and if mixing ratio influences the viscosity of the drop, the spread on Kromekote cards may be affected in turn. Therefore, the purpose of this study was to perform a cursory determination of the effect of mixing ratio on drop spread factor.

The details of the data for this study are presented in Appendixes III and IV and are summarized in Tables XI and XII, where data are presented for 13:1 and 17:1 mixing ratios, respectively. For both of these ratios, spot checks were made that covered an appreciable portion of the drop size range of interest. No statistical treatment of this data was attempted. However, corresponding spherical-drop and card-spot data are depicted in the graphical plots of Figures 3 and 4. The goodness of fit of the data for these experimental ratios with the normal 15:1 mixing ratio data suggests that, within the limits of the experimental data, there is little difference in spread factor for drops formed from Bifluid mixtures with mixing ratios varying from 13:1 to 17:1.

3. SPREAD FACTOR STUDIES ON PLANT LEAVES

Unlike the Kromekote card studies, the spread factor study with plant leaves was without precedence and, therefore, embraced unforseen difficulties and circumstances. The nonuniformity of the plant leaf structure made drop spot measurement more difficult than Kromekote card spot measurement, and measurements were only attempted on drops not deposited on the veined portion of the leaf. Nearly every type of plant leaf was different in some aspect. The drops were more readily absorbed on some leaf types than others, and, in some cases, this precluded the possibility of drop measurement beyond the second day. The rapidity of wilt varied according to species, which also limited spot measurements to no more than two days in some cases.

A halo formed around the Stull Bifluid drop spots on the silver maple leaves within one day after drop application. A similar halo appeared by the second day on the ORANGE-treated leaves. This halo effect led to erroneous spot measurements on the first two days after treatment, and data obtained were therefore rejected as invalid.

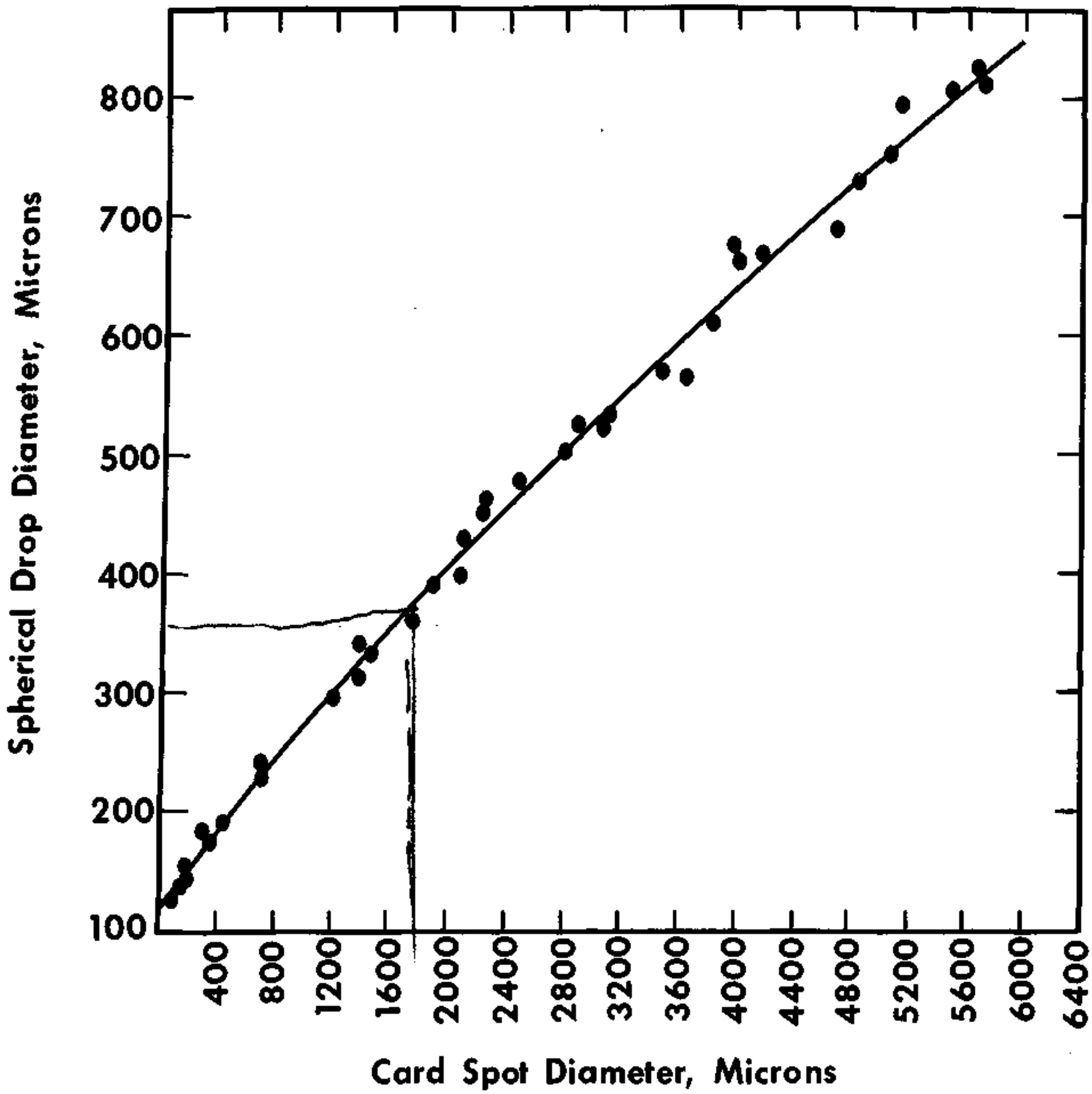

Figure 1. Correlation of Spherical Drop Size and Kromekote Card Spot Size for ORANGE Defoliant, Showing Quadratic Line Plot. The Quadratic Line Equation is: Drop Diameter = 26.22 + 0.14785 Card Spot Diameter - 4.42×10^{-6} (Card Spot Diameter)^2.

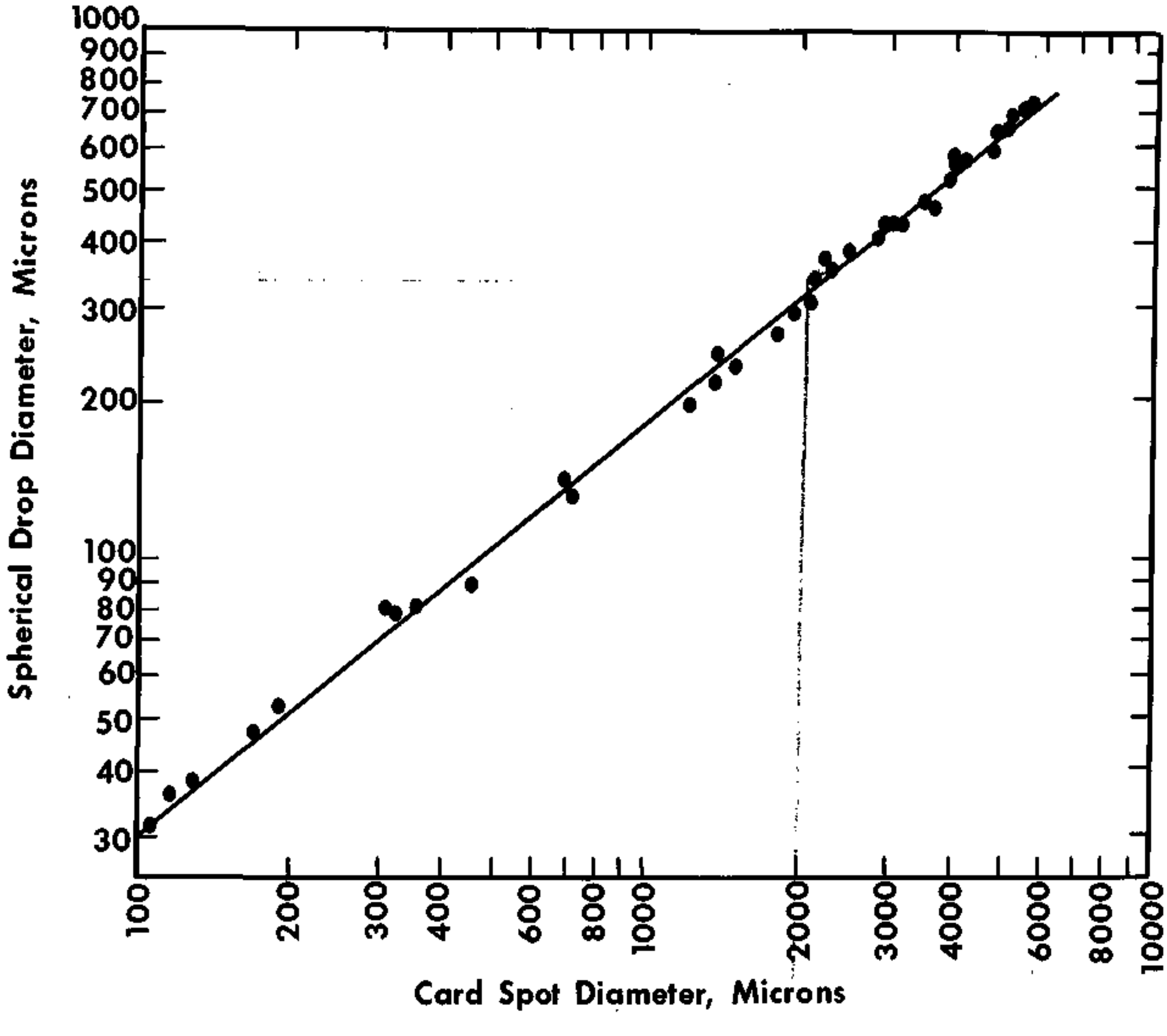

Figure 2. Log-Log Correlation of Spherical Drop Size and Kromekote Card Spot Size for ORANGE, Showing Best-Fit Line Plot. The Log-Log Line Equation is: Log Spherical Drop Diameter = -0.079619 + 0.779948 Log Card Spot Diameter.

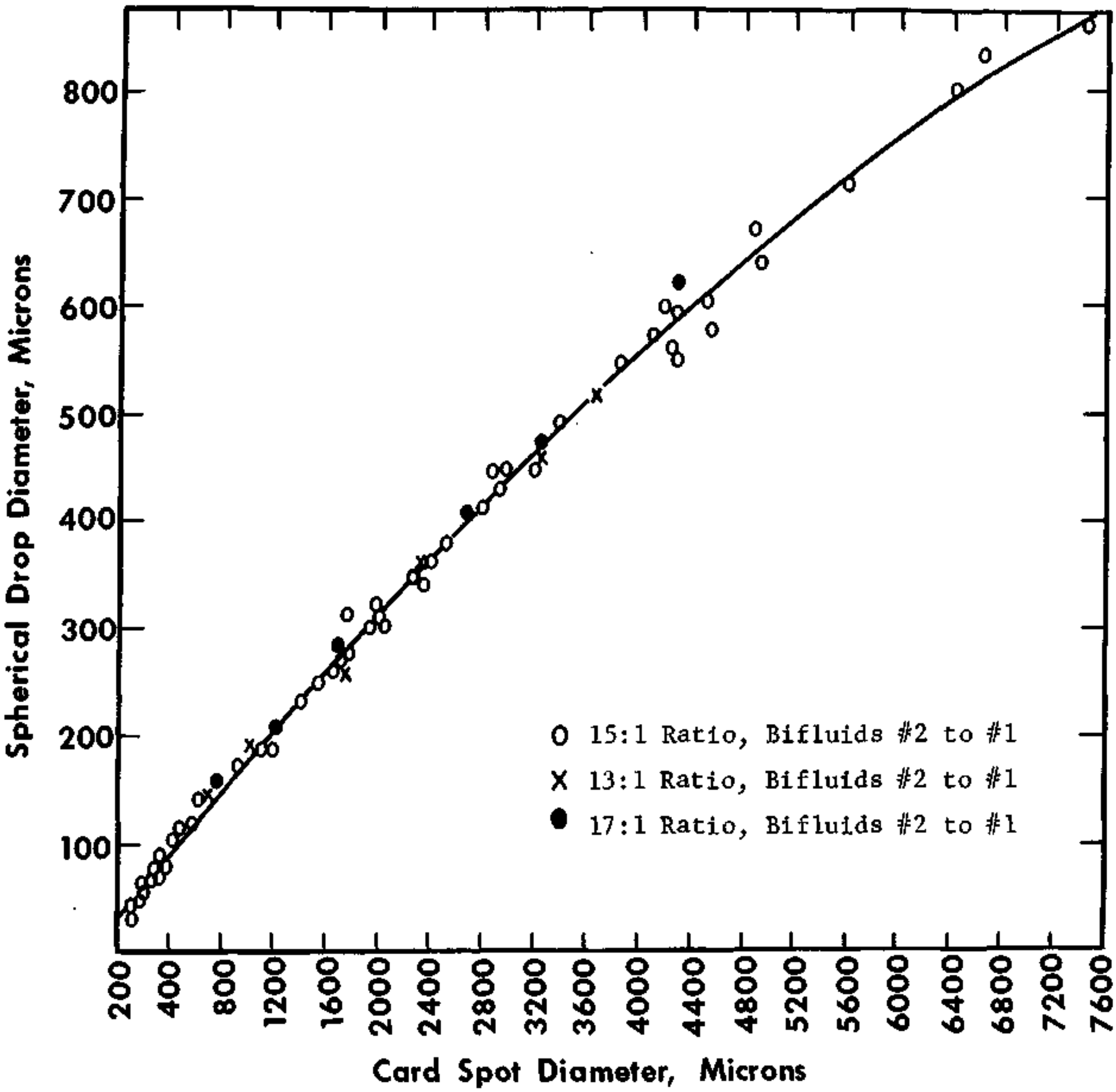

Figure 3. Correlation of Spherical Drop Size and Kromekote Card Spot Size for the Three Stull Bifluid Defoliant Mixing Ratios Tested, Showing Quadratic Line Plot. The Quadratic Line Equation is: Drop Diameter = 28.46 + 0.15303 Card Spot Diameter - 5.30 x 10^{-6} (Card Spot Diameter)^2.

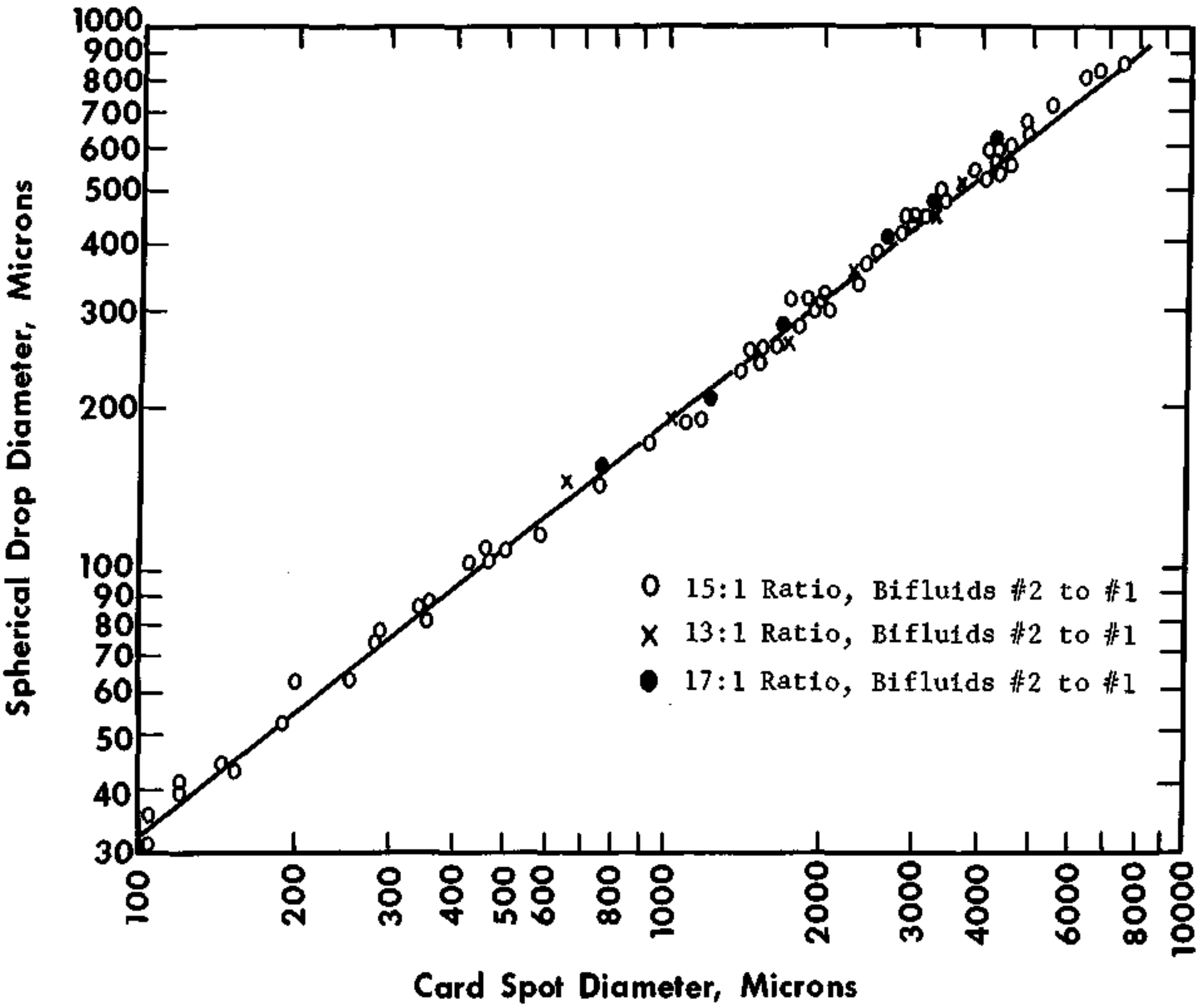

Figure 4. Log-Log Correlation of Spherical Drop Size and Kromekote Card Spot Size for the Three Stull Bifluid Mixing Ratios Tested, Showing Best-Fit Line Plot. The Log-Log Line Equation is: Log Spherical Drop Diameter = -0.01484 + 0.759132 Log Card Spot Diameter.

TABLE IX. ORANGE DEFOLIANT: CALCULATED DROP SIZE AND SPREAD FACTOR

Card spot, microns	Quadratic fit: Drop size, microns	Quadratic fit: S.F.	Log-log fit: Drop size, microns	Log-log fit: S.F.
100	40.96	2.441	30.22	3.309
200	55.61	3.596	51.89	3.854
300	70.17	4.275	71.19	4.214
400	84.65	4.725	89.09	4.490
500	99.04	5.048	106.03	4.716
600	113.34	5.294	122.23	4.909
800	141.67	5.647	152.98	5.229
1000	169.64	5.895	182.06	5.493
1200	197.27	6.083	209.89	5.717
1400	224.54	6.235	236.70	5.915
1600	251.46	6.363	262.68	6.091
1800	278.02	6.474	287.95	6.251
2000	304.22	6.574	312.61	6.398
2200	330.08	6.665	336.65	6.535
2400	355.58	6.750	360.39	6.659
2600	380.73	6.829	383.60	6.778
2800	405.52	6.905	406.44	6.889
3000	429.96	6.977	428.90	6.995
3200	454.04	7.048	451.04	7.095
3400	477.77	7.116	472.88	7.190
3600	501.15	7.183	494.43	7.281
3800	524.17	7.250	515.72	7.368
4000	546.84	7.315	536.79	7.452
4200	569.16	7.379	557.61	7.532
4400	591.12	7.443	578.20	7.610
4600	612.72	7.508	598.60	7.684
4800	633.98	7.571	618.81	7.757
5000	654.88	7.635	638.84	7.827
5200	675.42	7.699	658.67	7.895
5400	695.61	7.763	678.34	7.961
5600	715.45	7.827	697.88	8.024
5800	734.93	7.892	717.23	8.087
6000	754.06	7.957	736.45	8.147

TABLE X. STULL BIFLUID DEFOLIANT: CALCULATED DROP SIZE AND SPREAD FACTOR

Card spot, microns	Quadratic fit: Drop size, microns	Quadratic fit: S.F.	Log-log fit: Drop size, microns	Log-log fit: S.F.
100	43.71	2.288	32.87	3.042
200	58.85	3.398	55.63	3.595
300	73.90	4.060	75.68	3.964
400	88.82	4.503	94.15	4.248
500	103.66	4.823	111.53	4.483
600	118.38	5.068	128.09	4.684
800	147.50	5.424	159.34	5.021
1000	176.20	5.675	188.76	5.298
1200	204.47	5.869	216.78	5.536
1400	232.32	6.026	243.69	5.745
1600	259.75	6.160	269.69	5.933
1800	286.75	6.277	294.91	6.104
2000	313.33	6.383	319.47	6.260
2200	339.48	6.480	343.44	6.406
2400	365.21	6.572	366.89	6.541
2600	390.52	6.658	389.87	6.669
2800	415.40	6.740	412.44	6.789
3000	439.86	6.820	434.62	6.902
3200	463.89	6.898	456.44	7.011
3400	487.50	6.974	477.93	7.114
3600	510.69	7.049	499.14	7.212
3800	533.45	7.123	520.04	7.307
4000	555.79	7.197	540.69	7.398
4200	577.71	7.270	561.10	7.485
4400	599.20	7.343	581.26	7.570
4600	620.27	7.416	601.21	7.651
4800	640.91	7.489	620.96	7.730
5000	661.13	7.563	640.50	7.806
5200	680.92	7.637	659.86	7.880
5400	700.29	7.711	679.03	7.952
5600	719.24	7.786	698.03	8.022
5800	737.76	7.862	716.90	8.090
6000	755.86	7.938	735.58	8.157
6200	773.54	8.015	754.12	8.222
6400	790.79	8.093	772.52	8.284
6600	807.62	8.172	790.77	8.346
6800	824.02	8.252	808.92	8.406
7000	840.00	8.333	826.90	8.465
7200	855.56	8.416	844.78	8.523
7400	870.69	8.499	862.52	8.580
7600	885.39	8.584	880.16	8.635
7800	899.68	8.670	897.68	8.689
8000	913.54	8.757	915.12	8.742

TABLE XI. SUMMARY OF STULL BIFLUID 13:1 MIXING RATIO RAW DATA ANALYSIS

Sample number	Spherical drop size, microns	Card spot size, microns	Experimental spread factor
1	144.8	643.8	4.4461
2	187.5	1026.1	5.4725
3	263.6	1731.9	6.5701
4	357.2	2311.0	6.4697
5	457.9	3266.2	7.1329
6	518.9	3645.2	7.0248

TABLE XII. SUMMARY OF STULL BIFLUID 17:1 MIXING RATIO RAW DATA ANALYSIS

Sample number	Spherical drop size, microns	Card spot size, microns	Experimental spread factor
1	154.9	757.1	4.8876
2	206.4	1213.1	5.8774
3	280.8	1698.1	6.0484
4	408.1	2655.9	6.5079
5	466.3	3251.7	6.9734
6	619.5	4270.9	6.8941

All leaf spot measurements were made on intact plants, except for the dwarf brush cherry. In this case, the leaves were oriented on a nearly vertical plane and made intact leaf spot measurement impossible. Leaves were removed each day for spot measurement. The smallness of both the dwarf brush cherry and live oak leaves required that more than one leaf be treated with Stull Bifluid and ORANGE drops. For all other plant types, measurements were made on the same leaf each day, but not necessarily the same spots were measured.

Two spinning cups were employed to produce drops of Stull Bifluid and ORANGE. An attempt was made to produce drops of comparable size for both materials and to apply these drops on leaves of similar appearance as could be best judged by visual examination. Despite best efforts, drops of equal size were not always maintained between the two materials. However, drops roughly approximating three sizes were maintained. These sizes were arbitrarily chosen as spherical diameters of 100, 250, and 500 microns. The data presented show that the spread factor did not significantly change over this size range, and therefore, small deviations from the selected sizes should not materially affect the comparisons made between ORANGE and Stull Bifluid. In all cases, plant leaf spread factors were much less than those obtained with Kromekote cards and had experimental values between 1.3 and 2.5. Absorption of the spots into the leaf and leaf wilt due to herbicidal effects rarely permitted spread factor determinations beyond the second day after application. In some instances, absorption of the drop material actually reduced the spread factor value due to a reduction in the measured leaf spot sizes.

Appendixes V through X present the raw data obtained for the various plant leaf samples investigated. Ten spherical drop size measurements were made for each drop size. Three replicate plant leaf samples were obtained for each spherical drop size, and with few exceptions, ten leaf spots were measured per replicate. Tables XIII through XVIII summarize the raw data. Tables XIX through XXIV depict the mean spread factors for the various plant species along with a comparative value expressed as the Stull-Bifluid:ORANGE spread factor ratio. With few exceptions (notably Red Kidney bean), various statistical tests showed no significant differences between the drop spread of ORANGE and Stull Bifluid at the 5% level. The spread factor ratio was highly random, and spread factor ratio values approaching unity indicate little difference between Stull Bifluid and ORANGE drop spread. Spread factor ratios varied between 0.85 and 1.45 for all samples of all types of plants tested.

TABLE XIII. SUMMARY OF RED KIDNEY BEAN PLANT RAW DATA

Agent	Sample number	Spherical drop size, microns	Leaf spot size, microns[a] Day 1	Day 2	Day 3	Spread factor[a] Day 1	Day 2	Day 3
ORANGE	1-1	126.0	187.2	169.7	166.3	1.4857	1.3468	1.3198
Stull Bifluid	1-1	122.0	178.7	192.4	209.9	1.4648	1.5770	1.7204
ORANGE	1-2	126.0	173.4	164.9	163.5	1.3762	1.3087	1.2976
Stull Bifluid	1-2	122.0	178.7	182.0	213.3	1.4648	1.4918	1.7483
ORANGE	1-3	126.0	182.9	178.7	175.8	1.4516	1.4182	1.3952
Stull Bifluid	1-3	122.0	172.5	209.0	198.6	1.4139	1.7131	1.6278
ORANGE	1-4	126.0	174.9	179.1	176.8	1.3881	1.4214	1.4031
Stull Bifluid	1-4	122.0	181.0	172.0	175.8	1.4836	1.4098	1.4409
ORANGE	2-1	267.0	391.0	421.8	422.7	1.4644	1.5797	1.5831
Stull Bifluid	2-1	267.3	418.0	459.2	443.6	1.5637	1.7179	1.6595
ORANGE	2-2	267.0	413.7	442.1	434.1	1.5494	1.6558	1.6258
Stull Bifluid	2-2	267.3	413.7	454.0	452.6	1.5476	1.6984	1.6932
ORANGE	2-3	267.0	411.3	432.7	421.3	1.5404	1.6205	1.5779
Stull Bifluid	2-3	267.3	426.5	492.4	494.3	1.5955	1.8421	1.8492
ORANGE	3-1	502.0	852.5	885.7	854.4	1.6982	1.7643	1.7019
Stull Bifluid	3-1	491.0	804.7	1025.0	891.4	1.6389	2.0875	1.8154
ORANGE	3-2	502.0	833.1	919.8	934.1	1.6595	1.8322	1.8607
Stull Bifluid	3-2	491.0	842.1	991.4	986.2	1.7150	2.0191	2.0085
ORANGE	3-3	502.0	841.6	876.2	881.0	1.6764	1.7454	1.7549
Stull Bifluid	3-3	491.0	819.8	864.9	881.5	1.6696	1.7615	1.7953

a. Day 1 was day of application.

TABLE XIV. SUMMARY OF BLACK VALENTINE BEAN PLANT RAW DATA

Agent	Sample number	Spherical drop size, microns	Leaf size,[a] microns		Spread factor[a]	
			Day 1	Day 2	Day 1	Day 2
ORANGE	1-1	493.2	899.9	938.8	1.8246	1.9034
Stull Bifluid	1-1	494.9	835.0	908.9	1.6872	1.8376
ORANGE	1-2	493.2	875.8	928.8	1.7757	1.8832
Stull Bifluid	1-2	494.9	863.0	904.2	1.7437	1.8270
ORANGE	1-3	493.2	873.4	836.9	1.7708	1.6968
Stull Bifluid	1-3	494.9	851.6	889.5	1.7207	1.7973
ORANGE	2-1	259.8	405.2	438.8	1.5596	1.6889
Stull Bifluid	2-1	264.0	447.4	495.7	1.6946	1.8776
ORANGE	2-2	259.8	416.1	429.4	1.6061	1.6528
Stull Bifluid	2-2	264.0	449.3	430.3	1.7018	1.6299
ORANGE	2-3	259.8	420.3	432.7	1.6177	1.6655
Stull Bifluid	2-3	264.0	423.2	377.8	1.6030	1.4310
ORANGE	3-1	110.6	188.1	195.7	1.7007	1.7694
Stull Bifluid	3-1	111.4	184.3	173.4	1.6543	1.5565
ORANGE	3-2	110.6	196.2	206.6	1.7739	1.8679
Stull Bifluid	3-2	111.4	170.6	185.8	1.5314	1.6678
ORANGE	3-3	110.6	146.4	137.0	1.3236	1.2386
Stull Bifluid	3-3	111.4	159.2	145.5	1.4290	1.3061

a. Day 1 was day of application.

TABLE XV. SUMMARY OF SILVER MAPLE TREE RAW DATA

Agent	Sample number	Spherical drop size, microns	Leaf spot size, microns, on day 3[a]	Spread factor
ORANGE	1-1	137.0	233.8	1.7065
Stull Bifluid	1-1	140.0	253.9	1.8135
ORANGE	1-2	137.0	210.7	1.5379
Stull Bifluid	1-2	140.0	246.0	1.7571
ORANGE	1-3	137.0	201.4	1.4700
Stull Bifluid	1-3	140.0	215.2	1.5371
ORANGE	2-1	251.0	480.8	1.9155
Stull Bifluid	2-1	237.0	586.6	2.4751
ORANGE	2-2	251.0	528.8	2.1067
Stull Bifluid	2-2	237.0	462.7	1.9523
ORANGE	2-3	251.0	438.1	1.7454
Stull Bifluid	2-3	237.0	465.6	1.9645
ORANGE	3-1	498.0	959.6	1.9269
Stull Bifluid	3-1	496.0	909.6	1.8338
ORANGE	3-2	498.0	1236.5	2.4829
Stull Bifluid	3-2	496.0	910.6	1.8358
ORANGE	3-3	498.0	1101.3	2.2114
Stull Bifluid	3-3	496.0	997.4	2.0108

a. Two days after day of application.

TABLE XVI. SUMMARY OF GREEN ASH TREE RAW DATA

Agent	Sample number	Spherical drop size, microns	Leaf spot size,[a] microns		Spread factor[a]	
			Day 1	Day 2	Day 1	Day 2
ORANGE	1-1	500.2	890.5	935.1	1.7802	1.8694
Stull Bifluid	1-1	522.9	880.5	931.7	1.6838	1.7824
ORANGE	1-2	500.2	993.8	937.6	1.9868	1.8744
Stull Bifluid	1-2	522.9	868.2	926.3	1.6603	1.7721
ORANGE	1-3	500.2	994.7	1037.5	1.9886	2.0741
Stull Bifluid	1-3	522.9	1026.5	1083.6	1.9630	2.0722
ORANGE	2-1	256.3	412.2	435.5	1.6082	1.6991
Stull Bifluid	2-1	261.6	440.1	485.3	1.6823	1.8551
ORANGE	2-2	256.3	381.3	416.6	1.4877	1.6254
Stull Bifluid	2-2	261.6	412.2	592.4	1.5756	2.2645
ORANGE	2-3	256.3	423.9	446.4	1.6539	1.7417
Stull Bifluid	2-3	261.6	434.2	520.3	1.6597	1.9889
ORANGE	3-1	145.3	229.8	208.0	1.5815	1.4315
Stull Bifluid	3-1	156.9	273.4	289.1	1.7425	1.8425
ORANGE	3-2	145.3	260.6	261.6	1.7935	1.8004
Stull Bifluid	3-2	156.9	266.3	288.6	1.6972	1.8393
ORANGE	3-3	145.3	222.7	232.2	1.5326	1.5980
Stull Bifluid	3-3	156.9	268.7	258.3	1.7125	1.6462

a. Day 1 was day of application.

TABLE XVII. SUMMARY OF DWARF BRUSH CHERRY RAW DATA

Agent	Sample number	Spherical drop size, microns	Leaf spot size,[a] microns		Spread factor[a]	
			Day 1	Day 2	Day 1	Day 2
ORANGE	1-1	497.4	827.3	842.0	1.6632	1.6928
Stull Bifluid	1-1	465.3	892.5	847.9	1.9181	1.8223
ORANGE	1-2	497.4	853.8	884.6	1.7165	1.7784
Stull Bifluid	1-2	465.3	795.4	789.6	1.7094	1.6970
ORANGE	1-3	497.4	859.6	894.9	1.7281	1.7992
Stull Bifluid	1-3	465.3	823.4	852.3	1.7696	1.8317
ORANGE	2-1	256.3	405.2	471.1	1.5809	1.8380
Stull Bifluid	2-1	241.1	411.8	440.7	1.7080	1.8278
ORANGE	2-2	256.3	405.2	457.8	1.5809	1.7861
Stull Bifluid	2-2	241.1	413.7	491.0	1.7158	2.0364
ORANGE	2-3	256.3	391.9	474.8	1.5290	1.8525
Stull Bifluid	2-3	241.1	425.1	449.3	1.7631	1.8635
ORANGE	3-1	128.1	185.3	192.9	1.4465	1.5058
Stull Bifluid	3-1	128.6	183.9	199.0	1.4300	1.5474
ORANGE	3-2	128.1	194.3	191.5	1.5167	1.4949
Stull Bifluid	3-2	128.6	205.7	207.1	1.5995	1.6104
ORANGE	3-3	128.1	207.1	199.0	1.6167	1.5534
Stull Bifluid	3-3	128.6	196.2	229.8	1.5248	1.7869

a. Day 1 was day of application.

TABLE XVIII. SUMMARY OF LIVE OAK TREE RAW DATA

Agent	Sample number	Spherical drop size, microns	Leaf spot size,[a] microns		Spread factor[a]	
			Day 1	Day 2	Day 1	Day 2
ORANGE	1-1	493.2	837.4	934.5	1.6978	1.8947
Stull Bifluid	1-1	513.8	964.9	991.9	1.8779	1.9305
ORANGE	1-2	493.2	863.7	878.6	1.7512	1.7814
Stull Bifluid	1-2	513.8	990.0	1063.4	1.9268	2.0696
ORANGE	1-3	493.2	1044.5	1050.6	2.1178	2.1301
Stull Bifluid	1-3	513.8	929.3	981.9	1.8086	1.9110
ORANGE	2-1	249.2	380.5	399.0	1.5268	1.6011
Stull Bifluid	2-1	262.0	403.8	454.9	1.5412	1.7362
ORANGE	2-2	249.2	449.3	463.0	1.8029	1.8579
Stull Bifluid	2-2	262.0	416.1	495.2	1.5881	1.8900
ORANGE	2-3	249.2	401.9	427.9	1.6127	1.7170
Stull Bifluid	2-3	262.0	406.1	572.0	1.5500	2.1832
ORANGE	3-1	131.6	192.4	199.0	1.4620	1.5121
Stull Bifluid	3-1	133.3	260.2	318.0	1.9519	2.3855
ORANGE	3-2	131.6	188.6	184.8	1.4331	1.4042
Stull Bifluid	3-2	133.3	183.9	192.9	1.3795	1.4471
ORANGE	3-3	131.6	164.4	175.8	1.2492	1.3358
Stull Bifluid	3-3	133.3	260.2	318.5	1.9519	2.3893

a. Day 1 was day of application.

TABLE XIX. RED KIDNEY BEAN PLANT COMPARISONS

Agent	Spherical drop size, microns	Spread factor means[a]		
		Day 1	Day 2	Day 3
Stull Bifluid	122.0	1.4568^{xy}	1.5479^{wx}	1.6344^{w}
ORANGE	126.0	1.4254^{xy}	1.3738^{y}	1.3539^{y}
Stull-Bifluid:ORANGE spread factor ratio		1.0220	1.1267	1.2072
Stull Bifluid	267.3	1.5689^{xy}	1.7528^{w}	1.7340^{w}
ORANGE	267.0	1.5181^{y}	1.6187^{x}	1.5956^{xy}
Stull-Bifluid:ORANGE spread factor ratio		1.0335	1.0828	1.0867
Stull Bifluid	491.0	1.6745^{z}	1.9560^{w}	1.8731^{x}
ORANGE	502.0	1.6780^{z}	1.7806^{y}	1.7725^{y}
Stull-Bifluid:ORANGE spread factor ratio		0.9979	1.0985	1.0568

a. For each spherical-drop-size class, means having the same superscript are not significantly different at the 5% level when applying new Duncans Multiple Range Test.

TABLE XX. BLACK VALENTINE BEAN PLANT COMPARISONS

Agent	Spherical drop size, microns	Spread factor means[a]	
		Day 1	Day 2
Stull Bifluid	111.4	1.5382	1.5101
ORANGE	110.6	1.5994	1.6253
Stull-Bifluid:ORANGE spread factor ratio		0.9617	0.9291
Stull Bifluid	264.0	1.6665	1.6462
ORANGE	259.8	1.5945	1.6691
Stull-Bifluid:ORANGE spread factor ratio		1.0452	0.9863
Stull Bifluid	494.9	1.7172	1.8203
ORANGE	493.2	1.7904	1.8278
Stull-Bifluid:ORANGE spread factor ratio		0.9591	0.9959

a. For each drop-size class, there are no significant differences in the spread factors of the two materials as determined by analysis of variance at the 5% level.

TABLE XXI. SILVER MAPLE TREE COMPARISONS

Agent	Spherical drop size, microns	Spread factor means for day 3[a]
Stull Bifluid	140.0	1.7027
ORANGE	137.0	1.5715
Stull-Bifluid:ORANGE spread factor ratio		1.0835
Stull Bifluid	237.0	2.1306
ORANGE	251.0	1.9225
Stull-Bifluid:ORANGE spread factor ratio		1.1082
Stull Bifluid	496.0	1.8935
ORANGE	498.0	2.2071
Stull-Bifluid:ORANGE spread factor ratio		0.8579

a. Two days after day of application. For each spherical-drop-size class, there is no significant difference between means when applying T-test.

TABLE XXII. GREEN ASH TREE COMPARISONS

Agent	Spherical drop size, microns	Spread factor means[a]	
		Day 1	Day 2
Stull Bifluid	156.9	1.7174^{x}	1.7760^{x}
ORANGE	145.3	1.6359^{x}	1.6100^{x}
Stull-Bifluid:ORANGE spread factor ratio		1.0498	1.1031
Stull Bifluid	261.6	1.6392^{x}	2.0362^{y}
ORANGE	256.3	1.5833^{x}	1.6887^{x}
Stull-Bifluid:ORANGE spread factor ratio		1.0356	1.2057
Stull Bifluid	522.9	1.7690^{x}	1.8756^{x}
ORANGE	500.2	1.9185^{x}	1.9393^{x}
Stull-Bifluid:ORANGE spread factor ratio		0.9220	0.9671

a. For each spherical-drop-size class, means having the same superscript are not significantly different at the 5% level. The new Duncans Multiple Range test showed significant difference at the 5% level for the 250-micron size class.

TABLE XXIII. DWARF BRUSH CHERRY COMPARISONS

Agent	Spherical drop size, microns	Spread factor means[a/]	
		Day 1	Day 2
Stull Bifluid	128.6	1.5181[x]	1.6482[x]
ORANGE	128.1	1.5266[x]	1.5180[x]
Stull-Bifluid:ORANGE spread factor ratio		0.9944	1.0858
Stull Bifluid	241.1	1.7290[y]	1.9092[x]
ORANGE	256.3	1.5636[z]	1.8255[xy]
Stull-Bifluid:ORANGE spread factor ratio		1.1058	1.0459
Stull Bifluid	465.3	1.7990[x]	1.7837[x]
ORANGE	297.4	1.7026[x]	1.7568[x]
Stull-Bifluid:ORANGE spread factor ratio		1.0566	1.0153

a. For each spherical-drop-size class, means having the same superscript are not significantly different at the 5% level as determined by analysis of variance. The new Duncans Multiple Range test showed significant differences at the 5% level for the 250-micron size class.

TABLE XXIV. LIVE OAK TREE COMPARISONS

Agent	Spherical drop size, microns	Spread factor means[a/]	
		Day 1	Day 2
Stull Bifluid	133.3	1.7611	2.0740
ORANGE	131.6	1.3814	1.4174
Stull-Bifluid:ORANGE spread factor ratio		1.2749	1.4632
Stull Bifluid	262.0	1.5598	1.9365
ORANGE	249.2	1.6475	1.7253
Stull-Bifluid:ORANGE spread factor ratio		0.9468	1.1224
Stull Bifluid	513.8	1.8711	1.9704
ORANGE	493.2	1.8556	1.9354
Stull-Bifluid:ORANGE spread factor ratio		1.0084	1.0181

a. For each drop-size class there are no significant differences in the spread factors of the two materials as determined by analysis of variance at the 5% level.

SECTION V

CONCLUSIONS AND COMMENTS

For spread factor studies on Kromekote cards, the reader may make his own choice of one of the two best-fit line equations given for ORANGE and Stull Bifluid. Although a comparison of these equations in most cases showed statistically significant differences, examination of calculated values in Tables IX and X readily show that, between all equations, these differences rarely account for more than 20 microns in spherical drop size. Such differences may be well within the user's card spot measurement error. The validity of equations and numerical data generated therefrom is only valid for the experimental drop size and card spot size investigated. Extrapolation beyond the limits of the experimental results is not recommended.

It is difficult to state unequivocally that Stull Bifluid spreads more on plant leaves than ORANGE. A close examination of the summarized data in Tables XIII through XVIII shows that maximum drop spread varied; in some cases, the maximum drop spread was observed on the first day, while spread increased with additional time in other cases. In some instances, one can only speculate as to whether maximum spread was ever achieved within the time frame allotted for leaf spot measurement. Moreover, it is not certain that the day-to-day variations in spread factor were not in part due to measurement of different leaf spots for each day. Had leaf spot measurements been extended to longer time periods, the data may have provided more conclusive results. Certainly, Tables XIII through XVIII show that no large differences were apparent between Stull Bifluid and ORANGE drops.

Assuming that day-to-day or drop size variations in spread factor are of little practical significance, the spread factor data were pooled to obtain mean spread factors for each plant species. In addition, overall mean spread factors were determined disregarding day-to-day spot size or plant species effects. The resultant values thus determined are presented in Table XXV along with computed Stull-Bifluid:ORANGE ratios. This table shows that, with one exception, the Stull Bifluid drops spread slightly more than the ORANGE drops.

In this study, leaves of species for each of three types of plants (i.e., herbaceous, deciduous woody, and evergreen woody) were examined for comparative spread of Stull Bifluid and ORANGE drops. If it is assumed that jungle vegetation is a composite of these three basic types, it would appear from the foregoing that Stull Bifluid drops, on the average, would spread slightly more than ORANGE drops of the same size to produce more contact surface. On the other hand, other factors such as differences in drop size distributions of the emitted spray of the two fluids may far outweigh the small differences observed in this study. Although leaf contact area as related to phytotoxic effects is beyond the scope of this study, it should be stated that defoliants of the type employed in this study are primarily systemic rather than contact herbicides. Further, the validity of the above comparisons is clearly not without reproach for reasons previously cited.

TABLE XXV. OVERALL MEAN SPREAD FACTORS AND RATIOS FOR THE SIX PLANTS TESTED

Plant	Mean spread factors		Bifluid:ORANGE ratio
	Stull Bifluid	ORANGE	
Red Kidney Bean	1.6745	1.5498	1.0805
Black Valentine Bean	1.6498	1.6844	0.9795
Silver Maple	1.9089	1.9004	1.0047
Green Ash	1.8002	1.7293	1.0410
Dwarf Brush Cherry	1.7312	1.6489	1.0499
Live Oak	1.8621	1.6604	1.1215
Means	1.7712	1.6955	1.0462

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APPENDIX I

ORANGE AGENT RAW DATA ANALYSIS

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Microns	Spread Factor[b]
1	19.0		18	23	20.5		
	17.1		25	22	23.5		
	18.7		25	26	25.5		
	18.7		20	19	19.5		
	16.1		27	26	26.5		
	19.1		20	20	20.0		
	18.5		21	20	20.5		
	17.0		22	23	22.5		
	18.9		27	26	26.5		
	14.7		20	22	21.0		
Mean	17.8	31.2			22.6	105.4	3.3782
2	18.3		26	30	28.0		
	20.2		26	23	24.5		
	21.5		20	25	22.5		
	21.1		26	26	26.0		
	22.7		25	24	24.5		
	21.3		21	24	22.5		
	21.0		26	28	27.0		
	20.0		28	26	27.0		
	15.8		22	22	22.0		
	18.5		26	26	26.0		
Mean	20.0	35.1			25.0	116.6	3.3219
3	20.6		27	27	27.0		
	23.3		24	26	25.0		
	23.1		23	28	25.5		
	19.1		32	28	30.0		
	19.3		29	28	28.5		
	23.1		33	31	32.0		
	19.1		29	29	29.0		
	19.3		26	24	25.0		
	23.9		27	33	30.0		
	18.0		27	27	27.0		
Mean	20.9	36.6			27.9	130.1	3.5546
4	24.5		31	35	33.0		
	22.8		38	39	38.5		
	27.2		32	32	32.0		
	25.5		37	33	35.0		
	27.0		37	37	37.0		
	27.1		35	39	37.0		
	27.1		40	43	41.5		
	27.2		37	36	36.5		
	27.8		35	37	36.0		
	27.9		35	37	36.0		
Mean	26.4	46.3			36.3	169.2	3.6544

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Microns	Spread Factor[b]
5	29.5		35	44	39.5		
	31.4		40	40	40.0		
	30.0		39	40	39.5		
	29.2		40	39	39.5		
	29.9		42	40	41.0		
	27.1		39	39	39.0		
	30.5		44	40	42.0		
	30.1		39	42	40.5		
	29.6		41	42	41.5		
	30.4		41	41	41.0		
Mean	29.8	52.2			40.4	188.3	3.6072
6	42.8		70	72	71.0		
	42.9		77	82	79.5		
	48.3		64	62	63.0		
	43.9		64	70	67.0		
	42.5		74	67	70.5		
	44.3		69	70	69.5		
	42.7		65	66	65.5		
	41.8		73	75	74.0		
	47.0		68	64	66.0		
	43.0		65	71	68.0		
Mean	43.9	77.0			69.4	323.5	4.2012
7	44.6		64	68	66.0		
	45.0		67	62	64.5		
	43.0		80	77	78.5		
	44.8		63	71	67.0		
	45.1		71	73	72.0		
	45.4		75	72	73.5		
	44.7		67	69	68.0		
	45.0		69	72	70.5		
	45.0		61	65	63.0		
	44.2		67	75	71.0		
Mean	44.7	78.4			69.4	323.5	4.1262
8	47.3		71	63	67.0		
	46.0		74	70	72.0		
	47.9		61	56	58.5		
	47.3		71	74	72.5		
	42.9		73	67	70.0		
	43.7		52	57	54.5		
	47.2		64	66	65.0		
	45.5		65	69	67.0		
	47.0		66	61	63.5		
	46.1		70	75	72.5		
Mean	46.1	80.8			66.3	309.1	3.8254

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Microns	Spread Factor[b]
9	45.2		73	66	69.5		
	42.7		66	79	72.5		
	45.6		78	77	77.5		
	46.7		72	80	76.0		
	48.5		74	74	74.0		
	46.6		73	81	77.0		
	47.9		80	85	82.5		
	43.7		71	77	74.0		
	48.2		77	81	79.0		
	46.0		82	87	84.5		
Mean	46.1	80.8			76.7	357.6	4.4257
10	49.7		100	100	100.0		
	50.3		95	96	95.5		
	50.8		95	98	96.5		
	50.2		97	93	95.0		
	50.5		100	100	100.0		
	50.0		94	94	94.0		
	50.5		96	100	98.0		
	54.0		97	86	91.5		
	49.5		83	97	90.0		
	52.8		100	100	100.0		
Mean	50.8	89.1			96.1	448.0	5.0280
11	74.0		152	149	150.5		
	74.2		143	143	143.0		
	74.7		168	170	169.0		
	77.4		162	160	161.0		
	80.3		158	157	157.5		
	71.1		140	148	144.0		
	73.4		126	141	133.5		
	73.3		160	152	156.0		
	76.0		151	160	155.5		
	74.8		155	155	155.0		
Mean	74.9	131.3			152.6	711.4	5.4181
12	78.9		162	168	165.0		
	83.0		161	165	163.0		
	79.3		160	162	161.0		
	79.9		155	153	154.0		
	80.9		168	168	168.0		
	84.1		168	154	161.0		
	80.0		152	169	160.5		
	86.1		160	151	155.5		
	79.0		170	167	168.5		
	79.0		152	152	152.0		
Mean	81.0	142.0			160.9	705.1	4.9654

Sample No.	Spherical Drop Diameter		Card Spot Diameter				Spread Factor[b]
			Divisions[a]				
	Div.[a]	Microns	Meas. 1	Meas. 2	Mean	Microns	
13	107.8		263	239	251.0		
	110.3		271	256	263.5		
	113.1		256	251	253.5		
	112.0		249	237	243.0		
	109.0		243	257	250.0		
	115.3		295	270	282.5		
	109.9		235	264	249.5		
	109.8		246	256	251.0		
	110.7		262	260	261.0		
	105.7		273	271	262.0		
Mean	110.4	193.5			257.7	1201.4	6.2087
14	122.2		296	311	303.5		
	123.2		297	285	291.0		
	120.1		285	321	303.0		
	126.7		300	276	288.0		
	125.1		288	297	292.5		
	118.9		286	296	291.0		
	122.0		287	300	293.5		
	119.2		293	282	287.5		
	119.3		287	297	292.0		
	120.3		300	289	294.5		
Mean	121.7	213.4			293.7	1369.2	6.4161
15	66.0		287	289	288.0		
	65.9		297	295	296.0		
	65.5		311	317	314.0		
	66.9		316.5	304	310.5		
	67.0		327	326	326.5		
	65.9		317	334	323.5		
	66.5		317	326	321.5		
	66.1		308	321	315.0		
	67.3		329	335	332.0		
	66.6		331	327	329.0		
Mean	66.4	233.1			315.6	1471.3	6.3376
16	67.0		291	290	290.5		
	67.9		291	296	293.5		
	68.0		299	298	298.5		
	68.1		300	292	296.0		
	67.8		295	295	295.0		
	68.7		299	299	299.0		
	67.5		302	300	301.0		
	68.6		286	290	288.0		
	69.7		299	311	305.0		
	68.7		313	293	303.0		
Mean	68.2	239.4			297.0	1384.6	5.7836

Sample No.	Spherical Drop Diameter Div.[a]	Microns	Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Microns	Spread Factor[b]
17	74.1		394	348	371.0		
	74.5		378	387	382.5		
	73.7		378	378	378.0		
	74.5		365	389	377.0		
	73.5		392	392	392.0		
	74.5		399	387	393.0		
	74.6		395	381	388.0		
	74.6		395	381	388.0		
	74.4		373	360	366.5		
	74.9		389	358	373.5		
Mean	74.3	260.8			380.9	1775.6	6.8082
18	166.1		413	405	409.0		
	164.4		420	400	410.0		
	165.8		439	400	419.5		
	165.8		396	432	414.0		
	164.1		433	400	416.5		
	161.4		414	420	417.0		
	165.9		418	410	414.0		
	165.0		410	398	404.0		
	166.9		414	402	408.0		
	165.9		392	411	401.5		
Mean	165.1	289.4			411.4	1917.9	6.6271
19	87.0		429	472	445.5		
	84.1		450	453	451.5		
	84.5		485	511	498.0		
	86.7		413	429	421.0		
	86.0		451	445	448.0		
	83.5		428	458	443.0		
	86.3		463	471	467.0		
	86.3		458	430	444.0		
	85.7		452	459	455.5		
	86.1		408	429	418.5		
Mean	85.6	300.5			449.2	2094.2	6.9690
20	97.6		450	415	432.5		
	96.1		434	471	452.5		
	96.1		473	482	477.5		
	95.0		428	437	432.5		
	92.6		480	473	476.5		
	91.9		449	468	458.5		
	93.6		440	439	439.5		
	94.3		471	455	463.0		
	94.3		434	464	449.0		
	95.5		431	446	438.5		
Mean	94.7	332.4			452.0	2107.2	6.3393

Sample No.	Spherical Drop Diameter Div.[a]	Microns	Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Microns	Spread Factor[b]
21	206.2		456	435	445.5		
	202.7		438	471	454.5		
	195.0		466	457	458.5		
	207.4		457	493	475.0		
	205.3		493	484	488.5		
	202.6		485	500	492.5		
	205.7		523	513	518.0		
	198.9		500	517	508.5		
	205.5		527	494	510.5		
	202.7		494	496	495.0		
Mean	203.2	356.2			484.7	2259.7	6.3439
22	102.0		482	500	491.0		
	102.4		513	465	489.0		
	102.9		482	529	505.5		
	103.4		526	495	510.5		
	100.6		462	534	498.0		
	101.9		500	460	480.0		
	103.2		486	488	487.0		
	104.1		480	449	464.5		
	106.6		454	440	447.0		
	104.8		459	427	443.0		
Mean	103.2	362.3			481.6	2245.2	6.1970
23	104.6		543	534	538.5		
	103.2		522	469	495.5		
	106.4		500	514	507.0		
	104.8		534	520	527.0		
	106.1		522	537	529.5		
	108.1		550	540	545.0		
	111.1		568	538	553.0		
	113.2		526	528	527.0		
	111.0		536	558	547.0		
	111.4		575	533	554.0		
Mean	108.0	379.1			532.4	2482.0	6.5470
24	114.5		600	635	617.5		
	119.7		646	623	634.5		
	116.5		600	635	617.5		
	114.6		665	608	636.5		
	113.3		623	611	617.0		
	115.8		629	592	610.5		
	114.1		578	609	593.5		
	116.7		600	526	563.0		
	119.9		582	590	586.0		
	117.7		578	595	586.5		
Mean	116.3	408.3			606.3	2826.6	6.9228

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Card Spot Diameter Divisions[a] Meas. 1	Card Spot Diameter Divisions[a] Meas. 2	Card Spot Diameter Divisions[a] Mean	Card Spot Diameter Microns	Spread Factor[b]
25	122.4		586	605	595.5		
	120.0		595	593	594.0		
	123.7		632	644	638.0		
	120.9		629	600	614.5		
	119.6		636	664	650.0		
	120.3		675	625	650.0		
	121.3		640	680	660.0		
	120.0		645	616	630.5		
	121.5		600	640	620.0		
	121.9		600	600	600.0		
Mean	121.2	425.5			625.3	2915.1	6.8509
26	122.2		660	640	650.0		
	122.6		624	691	657.5		
	120.1		677	673	675.0		
	121.2		642	656	649.0		
	122.6		680	658	669.0		
	119.9		617	717	667.0		
	119.9		732	643	687.5		
	119.4		640	717	678.5		
	122.1						
Mean	121.3	425.8			666.7	3108.2	7.2996
27	124.7		726	651	688.5		
	123.9		611	665	638.0		
	122.6		668	690	679.0		
	121.7		629	705	667.0		
	121.7		680	663	671.5		
	121.5		603	650	626.5		
	119.9		671	653	662.0		
	122.2		641	731	636.0		
	122.2		637	693	665.0		
	122.2		677	676	676.5		
Mean	122.3	429.3			661.0	3081.6	7.1781
28	130.8		803	758	780.5		
	135.7		819	882	850.5		
	130.2		764	793	779.0		
	131.5		730	777	758.5		
	130.2		825	767	796.0		
	129.0		756	805	780.5		
	129.0		797	780	788.5		
	137.1		750	817	783.5		
	139.5		811	745	778.0		
	134.0		759	721	740.0		
Mean	132.7	465.8			783.5	3652.7	7.8417

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Card Spot Diameter Microns	Spread Factor[b]
29	134.7		723	822	772.5		
	133.0		819	734	776.5		
	131.7		732	785	758.5		
	137.4		780	769	774.5		
	134.6		746	800	773.0		
	135.4		752	712	732.0		
	139.5		754	788	771.0		
	137.2		768	745	756.5		
	133.0		710	744	727.0		
	132.9		648	624	636.0		
Mean	134.9	473.6			747.8	3486.2	7.3610
30	145.3		856	796	826.0		
	145.9		782	793	787.5		
	149.1		876	846	861.0		
	150.7		786	800	793.0		
	146.8		763	791	777.0		
	142.3		818	827	822.5		
	148.0		843	807	825.0		
	149.5		800	832	816.0		
	144.9		782	828	850.0		
	142.7		815	842	828.5		
Mean	146.5	514.3			818.7	3816.8	7.4213
31	156.5		890	924	907.0		
	157.6		831	849	840.0		
	160.9		851	932	891.5		
	157.0		900	858	879.0		
	163.6		854	983	918.5		
	164.4		863	781	822.0		
	158.9		842	900	871.0		
	163.7		865	800	832.5		
	163.7		816	800	808.0		
	160.9		848	765	806.5		
Mean	160.7	564.1			857.6	3998.1	7.0875
32	163.1		887	938	912.5		
	164.0		904	857	880.5		
	162.6		890	900	895.0		
	160.7		948	874	911.0		
	162.5		885	959	922.0		
	162.5		916	858	887.0		
	161.8		852	895	873.5		
	161.8		874	841	857.5		
	163.6		838	873	855.5		
	165.5		933	827	930.0		
Mean	162.8	571.5			892.5	4160.8	7.2804

Sample No.	Spherical Drop Diameter		Card Spot Diameter				Spread Factor[b]
			Divisions[a]				
	Div.[a]	Microns	Meas. 1	Meas. 2	Mean	Microns	
33	164.9		813	847	830.0		
	161.0		873	796	834.5		
	158.7		765	807	786.0		
	165.8		936	836	886.0		
	167.1		883	823	853.0		
	169.0		871	815	843.0		
	160.7		858	885	871.5		
	167.0		920	871	895.5		
	161.0		800	922	861.0		
	159.7		885	800	842.5		
Mean	163.5	574.0			850.3	3964.1	6.9060
34	165.5		1021	1019	1020.0		
	172.5		1019	1029	1024.0		
	168.0		1060	976	1018.0		
	171.1		1043	1029	1036.0		
	169.7		1036	1047	1041.5		
	164.5		1046	1047	1046.5		
	171.5		1070	1012	1041.0		
	167.1		1001	963	982.0		
	170.2		924	981	952.5		
	166.8		939	919	929.0		
Mean	168.7	592.2			1009.1	4704.4	7.9439
35	177.9		61	64	62.5		
	173.8		65	62	63.5		
	178.5		64	60	62.0		
	177.3		66	62	64.0		
	179.5		64	64	64.0		
	182.0		70	63	66.5		
	184.5		68	72	70.0		
	186.3		54	60	57.0		
	177.7		61	51	56.0		
	184.6		63	64	63.5		
Mean	180.2	632.6			62.9	4837.0	7.6462
36	186.6		65	63	64.0		
	190.1		69	67	68.0		
	184.1		62	64	63.0		
	189.1		68	66	67.0		
	186.7		67	65	66.0		
	189.0		70	67	68.5		
	188.7		67	67	67.0		
	183.0		66	65	65.5		
	182.1		66	64	65.0		
	188.4		60	64	62.0		
Mean	186.8	655.7			65.6	5044.6	7.6934

Sample No.	Spherical Drop Diameter Div.[a]	Microns	Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Microns	Spread Factor[b]
37	198.5		62	68	65.0		
	198.1		65	66	65.5		
	193.3		68	72	70.0		
	195.0		75	60	67.5		
	200.4		65	69	67.0		
	197.2		70	60	65.0		
	197.7		61	69	65.0		
	200.1		67	74	70.5		
	200.1		65	66	65.5		
	199.4		67	66	66.5		
Mean	198.8	695.1			66.8	5136.9	7.3901
38	192.5		73	76	74.5		
	200.1		77	74	75.5		
	204.6		69	75	72.0		
	203.6		76	70	73.0		
	201.8		71	76	73.5		
	206.4		77	71	74.0		
	201.9		60	71	65.5		
	203.1		74	65	69.0		
	203.1		63	73	68.0		
	205.0		73	61	67.5		
Mean	202.2	709.8			71.3	5483.0	7.7247
39	204.5		73	76	74.5		
	203.4		78	73	75.5		
	207.1		73	68	70.5		
	202.0		78	74	76.0		
	208.7		76	72	74.0		
	202.9		73	75	74.0		
	202.9		76	76	76.0		
	204.1		73	74	73.5		
	206.4		73	72	72.5		
	201.9		77	74	75.5		
Mean	204.4	717.5			74.2	5706.0	7.9526

Sample No.	Spherical Drop Diameter Div.[a]	Microns	Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Microns	Spread Factor[b]
40	208.9		80	73	76.5		
	210.2		73	83	78.0		
	205.1		80	76	78.0		
	208.5		73	83	78.0		
	212.3		85	69	77.0		
	206.2		77	80	78.5		
	209.2		70	63	66.5		
	207.5		63	72	67.5		
	205.6		74	63	68.5		
	205.7		64	69	66.5		
Mean	207.9	729.8			73.5	5652.2	7.7448

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
   1) For spherical drop measurements:
      a) Vickers Eyepiece #1 (10X objective), k = 1.7531 for Samples 1 to 14, 18, and 21.
      b) Vickers Eyepiece #2 (5X objective), k = 3.5104 for Samples 15 to 17, 19, 20, and 22 to 40.
   2) For card spot measurements:
      a) 12.5X Filar Eyepiece (2X objective), k = 4.662 for Samples 1 to 34.
      b) Stereomicroscope (20X objective), k = 76.9 for Samples 35 to 40.

b. Spherical drop diameter divided into card spot diameter.

APPENDIX II

STULL BIFLUID RAW DATA ANALYSIS

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Outside Card Spot Diameter Divisions[a] Meas. 2	Outside Card Spot Diameter Divisions[a] Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
1	18.5		23	21	22.0					
	18.5		22	24	23.0					
	18.5		21	21	21.0					
	18.5		21	22	21.5					
	18.5		20	22	21.0					
	19.0		23	21	22.0					
	18.5		22	21	21.5					
	18.5		21	21	21.0					
	18.0		21	22	21.5					
	18.5		20	21	20.5					
Mean	18.5	31.8			21.5	100.2			3.1509	
2	21.0		23	21	22.0					
	21.5		26	23	24.5					
	20.5		22	21	21.5					
	21.0		23	22	22.5					
	21.0		20	20	20.0					
	20.5		21	20	20.5					
	20.5		22	20	21.0					
	20.5		22	24	23.0					
	21.0		22	20	21.0					
	20.5		20	22	21.0					
Mean	20.8	35.7			21.7	101.2			2.8347	
3	23.5		27	26	26.5					
	23.0		25	28	26.5					
	23.0		25	25	25.0					
	23.0		23	24	23.5					
	22.5		28	24	26.0					
	22.5		27	24	25.5					
	22.5		25	24	24.5					
	24.0		25	27	26.0					
	23.0		27	23	25.0					
	22.0		24	26	25.0					
Mean	22.9	39.3			25.4	118.4			3.0127	

4	11.5		30	32	31.0		15			
	11.5		27	28	27.5		14			
	11.0		23	27	25.0		11			
	11.0		24	22	23.0		12			
	10.5		26	25	25.5		14			
	12.0		30	27	28.5		15			
	12.0		23	23	23.0		15			
	10.5		25	25	25.0		15			
	12.0		23	22	22.5		15			
	10.5		23	25	24.0		14			
Mean	11.3	40.0			25.5	118.9	14.0	65.3	2.9725	1.6325
5	12.5		33	31	32.0					
	12.5		33	34	33.5					
	12.5		31	34	32.5					
	12.5		34	33	33.5					
	12.5		32	33	32.5					
	12.5		34	32	33.0					
	12.5		32	30	31.0					
	12.5		31	31	31.0					
	12.5		34	33	33.5					
	12.5		31	34	32.5					
Mean	12.5	43.9			32.5	151.5			3.4510	
6	27.0		27	33	30.0		18			
	27.5		31	30	30.5		20			
	22.5		25	29	27.0		16			
	25.5		35	30	32.5		20			
	22.0		31	31	31.0		20			
	27.5		31	32	31.5		21			
	25.0		35	34	34.5		22			
	25.0		31	30	30.5		20			
	27.0		28	29	28.5		22			
	28.0		35	31	33.0		18			
Mean	25.7	44.0			30.9	144.1	19.7	91.8	3.2750	2.0863

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
7	15.0		44	42	43.0					
	15.0		43	38	40.5					
	15.0		40	40	40.0					
	15.0		36	42	39.0					
	15.0		42	37	39.5					
	15.0		37	39	38.0					
	15.0		41	43	42.0					
	15.0		40	39	39.5					
	15.0		38	37	37.5					
	15.0		40	39	39.5					
Mean	15.0	52.7			39.9	186.0			3.5294	
8	18.0		40	43	41.5		12			
	19.0		43	45	44.0		18			
	19.0		42	40	41.0		18			
	18.0		40	44	42.0		17			
	18.5		45	44	44.5		20			
	19.0		42	44	43.0		19			
	18.0		47	43	45.0		18			
	17.5		40	45	42.5		20			
	19.0		41	42	41.5		19			
	18.0		40	42	41.0		20			
Mean	18.4	62.0			42.6	198.6	18.1	84.4	3.2032	1.3612
9	18.0		53	52	52.5					
	18.0		53	55	54.0					
	18.0		51	50	50.5					
	18.0		52	51	51.5					
	18.0		57	57	57.0					
	18.0		58	54	56.0					
	18.0		56	55	55.5					
	18.0		50	53	51.5					
	18.0		53	56	54.5					
	18.0		57	55	56.0					
Mean	18.0	63.2			53.9	251.3			3.9762	

10	21.0		55	55	55.0		
	21.0		69	63	66.0		
	21.0		62	64	63.0		
	21.0		59	60	59.5		
	21.0		55	58	56.5		
	21.0		63	58	60.5		
	21.0		54	63	58.5		
	21.0		55	59	57.0		
	21.0		62	68	65.0		
	21.0		62	58	60.0		
Mean	21.0	73.7			60.1	280.2	3.8018
11	21.0		63	64	63.5		
	21.0		66	62	64.0		
	21.0		59	60	59.5		
	22.0		59	59	59.0		
	21.0		59	61	60.0		
	22.0		60	58	59.0		
	21.0		66	64	65.0		
	21.0		58	63	60.5		
	22.0		65	66	65.5		
	21.0		63	60	61.5		
Mean	21.3	74.8			61.8	288.1	3.8516
12	22.5		83	81	82.0		
	22.5		71	69	70.0		
	22.5		75	73	74.0		
	22.5		88	81	84.5		
	22.5		77	79	78.0		
	22.5		81	69	80.0		
	22.5		64	68	66.0		
	22.5		78	79	78.5		
	22.5		73	73	73.0		
	22.5		72	69	70.5		
Mean	22.5	80.0			75.7	352.9	4.4112

Sample No.	Spherical Drop Diameter: Div.[a]	Spherical Drop Diameter: Microns	Outside Card Spot Diameter, Divisions[a]: Meas. 1	Outside Card Spot Diameter, Divisions[a]: Meas. 2	Outside Card Spot Diameter, Divisions[a]: Mean	Outside Card Spot Diameter: Microns	Center Card Spot Diameter: Div.[a]	Center Card Spot Diameter: Microns	Spread Factors[b]: Outer Spot	Spread Factors[b]: Center Spot
13	24.5		78	79	78.5		27			
	23.5		67	70	68.5		28			
	24.5		68	70	69.0		30			
	24.5		77	85	81.0		30			
	24.5		75	73	74.0		30			
	22.5		80	83	81.5		29			
	23.5		70	69	69.5		29			
	24.5		73	72	72.5		27			
	24.5		75	76	75.5		29			
	24.5		75	77	76.0		28			
Mean	24.1	84.6			74.6	347.8	28.7	133.8	4.1111	1.5815
14	25.0		76	78	77.0					
	25.0		76	70	73.0					
	25.0		75	76	75.5					
	25.0		77	71	74.0					
	25.0		71	77	74.0					
	25.0		77	78	77.5					
	25.0		68	74	71.0					
	25.0		81	80	80.5					
	25.0		79	80	79.5					
	25.0		80	76	78.0					
Mean	25.0	87.8			76.0	354.3			4.0353	

15	30.0		83	79	81.0		30			
	30.0		93	95	94.0		35			
	32.0		93	92	92.5		33			
	30.0		96	93	94.5		31			
	31.0		95	93	94.0		33			
	30.0		83	90	86.5		35			
	31.0		93	94	93.5		32			
	31.0		94	95	94.5		31			
	31.0		89	95	92.0		30			
	32.0		95	96	95.5		37			
Mean	30.8	103.7			91.8	428.0	32.7	152.4	4.1272	1.4696
16	31.0		100	105	102.5		41			
	31.0		98	97	97.5		41			
	31.0		100	95	97.5		39			
	31.0		98	100	99.0		41			
	31.0		93	96	94.5		38			
	31.0		108	100	104.0		39			
	31.0		97	96	96.5		42			
	31.0		105	100	102.5		38			
	31.0		98	100	99.0		38			
	31.0		97	96	96.5		38			
Mean	31.0	104.4			99.0	461.5	39.5	184.1	4.4204	1.7634
17	30.5		100	100	100.0					
	31.5		97	100	98.5					
	30.5		100	105	102.5					
	30.5		98	100	99.0					
	30.5		100	95	97.5					
	31.5		105	100	102.5					
	31.5		98	98	98.0					
	30.5		97	95	96.0					
	30.5		97	97	97.0					
	30.5		100	96	98.0					
Mean	30.8	108.1			98.9	461.1			4.2654	

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
18	31.0		94	100	97.0					
	31.0		111	119	115.0					
	31.0		100	113	106.5					
	31.0		105	100	102.5					
	31.0		118	114	116.0					
	31.0		100	100	100.0					
	31.0		106	100	103.0					
	31.0		113	108	110.5					
	31.0		108	105	106.5					
	31.0		110	103	106.5					
Mean	31.0	108.8			106.4	496.0			4.5588	
19	35.0		130	129	129.5		46			
	35.0		128	132	130.0		46			
	35.0		124	120	122.0		46			
	35.0		121	119	120.0		48			
	35.0		120	117	118.5		47			
	35.0		128	126	127.0		47			
	35.0		122	125	123.5		46			
	35.0		130	125	127.5		47			
	35.0		129	130	129.5		46			
	35.0		123	123	123.0		44			
Mean	35.0	117.8			125.1	583.2	46.3	215.9	4.9507	1.8327

20	43.0		162	163	162.5		59			
	43.0		160	164	162.0		57			
	43.0		171	156	163.5		58			
	43.0		150	147	148.5		54			
	42.0		151	149	150.0		56			
	43.0		162	162	162.0		55			
	43.0		155	161	158.0		56			
	43.0		167	165	166.0		55			
	43.0		174	159	166.5		56			
	43.0		156	157	156.5		57			
Mean	42.9	144.4			159.6	744.1	56.3	262.5	5.1530	1.8178
21	51.5		205	215	210.0		67			
	51.5		200	196	198.0		70			
	51.5		205	200	202.5		68			
	51.0		209	200	204.5		68			
	51.0		206	198	202.0		73			
	51.0		200	208	204.0		67			
	49.5		192	194	193.0		71			
	50.5		200	197	198.5		66			
	51.0		196	200	198.0		67			
	51.0		200	186	193.0		64			
Mean	51.0	171.7			200.4	934.3	68.1	317.5	5.4414	1.8491
22	55.0		200	289	244.5		62			
	55.0		222	232	227.0		73			
	55.0		232	220	226.0		70			
	56.0		211	234	222.5		72			
	56.5		229	238	233.5		73			
	54.5		236	218	227.0		66			
	56.0		208	326	267.0		72			
	56.0		233	234	233.5		72			
	55.0		223	240	231.5		71			
	56.0		240	219	229.5		77			
Mean	55.5	186.9			234.2	1091.8	70.8	330.1	5.8416	1.7661

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Outside Card Spot Diameter Divisions[a] Meas. 2	Outside Card Spot Diameter Divisions[a] Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
23	55.0		240	252	246.0		73			
	55.5		254	258	256.0		71			
	57.0		261	269	265.0		81			
	55.0		268	254	261.0		71			
	55.0		243	248	245.5		71			
	56.0		248	244	246.0		69			
	56.5		253	258	255.5		75			
	56.5		249	256	253.0		69			
	55.0		273	250	261.5		75			
	56.0		229	243	236.0		61			
Mean	55.8	187.9			252.6	1177.6	72.6	338.5	6.2671	1.8014
24	68.0		296	314	305.0		87			
	68.5		316	297	306.5		87			
	67.5		297	408	302.5		87			
	68.0		315	303	309.0		86			
	68.0		293	296	294.5		85			
	68.0		310	290	300.0		86			
	69.0		291	300	295.5		81			
	68.5		325	300	312.5		82			
	68.5		298	307	302.5		85			
	69.0		300	290	295.0		87			
Mean	68.3	230.0			302.3	1409.3	85.3	397.7	6.1273	1.7291

25	74.0		321	334	327.5		75			
	74.0		346	330	338.0		72			
	74.0		326	340	332.0		82			
	74.0		331	324	327.5		88			
	74.0		328	341	335.0		82			
	74.0		334	310	324.0		88			
	74.0		325	332	328.5		91			
	74.0		337	327	332.0		92			
	74.0		327	340	332.5		83			
	74.0		343	325	334.0		89			
Mean	74.0	249.2			331.1	1543.6	84.2	392.5	6.1942	1.5750
26	74.0		331	324	327.5		100			
	74.0		333	326	329.5		100			
	75.0		316	310	313.0		113			
	75.0		313	315	314.0		100			
	73.5		324	308	316.0		107			
	74.0		300	321	310.5		100			
	74.0		315	318	316.5		100			
	74.5		317	323	320.0		100			
	74.0		321	320	320.5		107			
	74.0		319	323	321.0		111			
Mean	74.2	249.8			318.9	1486.7	103.8	483.9	5.9515	1.9371
27	74.0		348	330	339.0		100			
	74.0		325	325	325.0		100			
	74.0		338	328	333.0		100			
	74.0		313	338	325.5		100			
	75.0		329	325	327.0		110			
	75.5		324	357	340.5		105			
	74.0		332	316	324.0		100			
	74.0		305	327	316.0		100			
	74.0		317	321	319.0		100			
	75.0		339	327	333.0		100			
Mean	74.4	250.5			327.8	1528.2	101.5	473.2	6.1005	1.8890

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Outside Card Spot Diameter Divisions[a] Meas. 2	Outside Card Spot Diameter Divisions[a] Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
28	80.0		361	330	345.5		82			
	81.5		300	363	331.5		80			
	78.5		360	338	349.0		90			
	78.5		351	362	356.5		93			
	79.5		372	351	366.5		90			
	80.0		342	351	346.0		92			
	80.5		371	352	361.5		92			
	79.0		345	363	354.0		96			
	80.5		383	338	360.5		95			
	79.5		340	363	351.5		87			
Mean	79.8	268.7			352.3	1642.4	89.7	418.2	6.1123	1.5563
29	81.5		348	373	360.5		100			
	81.0		371	369	370.0		100			
	80.0		373	394	383.5		100			
	80.5		368	352	360.0		90			
	81.5		358	372	365.0		100			
	80.0		389	356	372.5		100			
	81.5		354	383	368.5		100			
	81.5		394	388	391.0		100			
	81.5		356	378	367.0		100			
	81.5		374	374	374.0		100			
Mean	81.1	273.1			371.2	1730.5	99.0	461.5	6.3365	1.6898

30	84.5		384	363	373.5		90			
	82.0		364	385	374.5		90			
	84.5		364	355	359.5		90			
	81.5		376	387	381.5		84			
	82.5		382	374	378.0		93			
	81.5		367	400	383.5		90			
	83.5		396	387	391.5		90			
	81.5		359	385	372.0		93			
	82.0		380	365	372.5		89			
	81.5		377	400	388.5		95			
Mean	82.5	277.8			377.5	1759.9	90.4	421.4	6.3351	1.5169
31	89.5		404	409	406.5		100			
	89.5		414	404	409.0		103			
	87.5		425	421	423.0		100			
	90.5		421	400	411.5		100			
	89.0		400	426	413.0		100			
	89.5		423	397	410.0		100			
	89.5		413	415	414.0		100			
	89.5		431	400	415.5		100			
	89.0		410	415	412.5		102			
	92.0		430	396	413.0		100			
Mean	89.6	301.7			412.8	1924.5	100.5	468.5	6.3788	1.5528
32	90.0		439	423	431.0		100			
	90.0		427	437	432.0		107			
	90.0		437	425	431.0		110			
	90.0		418	438	428.0		100			
	90.0		439	412	425.5		100			
	91.0		425	451	438.0		100			
	91.0		442	441	441.5		100			
	90.0		409	436	422.5		100			
	90.0		447	417	432.0		113			
	90.0		421	427	424.0		113			
Mean	90.2	303.7			430.6	2007.5	104.3	486.2	6.6101	1.6009

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
33	90.5		418	400	409.0		100			
	91.0		400	443	421.5		109			
	89.5		428	405	416.5		100			
	89.0		405	441	423.0		115			
	88.0		444	408	426.0		105			
	90.5		416	426	421.0		100			
	92.0		441	426	433.5		118			
	92.5		416	424	420.0		100			
	92.0		442	422	432.0		115			
	90.5		407	441	424.0		100			
Mean	90.6	305.1			422.7	1970.6	106.2	495.1	6.4588	1.6227
34	89.5		369	392	380.5		85			
	93.0		364	362	363.0		100			
	93.5		350	364	357.0		100			
	93.5		383	372	375.5		100			
	92.5		388	394	391.0		100			
	89.0		393	369	381.0		100			
	91.0		336	354	345.0		100			
	92.0		379	369	374.0		100			
	93.0		368	396	382.0		100			
	93.5		385	392	388.5		118			
Mean	92.1	310.1			373.8	1742.7	100.3	467.6	5.6198	1.5079

35	94.0		443	421	432.0		100			
	94.0		412	445	428.5		106			
	94.5		434	404	419.0		100			
	94.5		409	422	415.5		100			
	94.5		462	415	438.5		100			
	98.0		409	429	419.0		100			
	94.0		423	413	408.0		100			
	93.0		410	447	428.5		100			
	94.0		445	406	425.5		100			
	93.5		424	436	430.0		100			
Mean	94.4	317.8			425.5	1983.7	100.6	469.0	6.2419	1.4757
36	91.0		397	448	422.5		112			
	91.0		455	421	438.0		115			
	91.0		396	432	414.0		100			
	93.5		424	407	415.5		118			
	89.0		432	424	428.0		100			
	94.5		440	412	426.0		116			
	90.5		429	428	428.5		108			
	89.5		430	448	439.0		111			
	89.0		424	433	428.5		110			
	90.5		447	428	437.5		100			
Mean	91.0	319.4			427.8	1994.4	109.0	508.2	6.2442	1.5911
37	101.0		493	500	496.5		138			
	95.0		528	460	494.0		138			
	99.0		486	521	503.5		134			
	100.0		506	481	493.5		130			
	100.5		493	518	505.5		122			
	97.5		494	459	476.5		131			
	99.5		485	527	506.0		134			
	---		517	504	510.5		127			
	96.0		500	524	512.0		134			
	97.5		500	495	497.5		123			
Mean	98.4	345.4			499.6	2329.1	131.1	611.2	6.7431	1.7695

Sample	Spherical Drop Diameter		Outside Card Spot Diameter				Center Card Spot Diameter		Spread Factors[b]	
			Divisions[a]						Outer	Center
No.	Div.[a]	Microns	Meas. 1	Meas. 2	Mean	Microns	Div.[a]	Microns	Spot	Spot
38	102.0		465	491	478.0		122			
	99.0		500	465	482.5		127			
	98.5		478	500	489.0		116			
	101.5		474	479	476.5		127			
	100.0		479	499	489.0		132			
	99.0		500	484	492.0		118			
	98.0		477	498	487.5		130			
	100.0		481	491	486.0		130			
	99.0		488	500	494.0		124			
	100.5		500	493	496.0		123			
Mean	99.8	350.3			487.1	2270.9	124.9	582.3	6.4827	1.6622
39	107.0		549	500	524.5		125			
	105.5		500	522	511.0		117			
	109.0		529	506	517.5		132			
	106.5		496	531	513.5		120			
	107.5		532	516	524.0		126			
	107.0		480	516	498.0		122			
	106.0		500	495	497.5		120			
	106.5		490	513	501.5		121			
	107.5		536	517	526.5		130			
	106.5		496	524	510.0		125			
Mean	106.9	359.9			512.4	2388.8	123.8	577.2	6.6373	1.6037

40	114.5		509	528	518.5		135			
	114.5		528	557	542.5		133			
	116.0		537	532	534.5		141			
	114.0		556	534	545.0		144			
	113.5		556	538	547.0		143			
	113.0		562	542	552.0		146			
	115.5		571	525	548.0		133			
	114.0		559	549	554.0		131			
	114.0		562	538	550.0		134			
	114.0		567	533	550.0		145			
Mean	114.3	384.8			544.2	2537.1	138.5	645.7	6.5932	1.6780
41	116.5		569	579	573.0		169			
	115.5		597	572	584.5		166			
	117.0		605	595	600.0		162			
	116.0		600	600	600.0		152			
	120.5		600	582	596.0		160			
	117.5		600	576	588.0		161			
	117.5		595	600	597.5		164			
	117.5		634	595	614.5		163			
	116.5		581	624	604.5		168			
	120.0		600	619	609.5		154			
Mean	117.5	412.5			596.8	2782.3	161.9	754.8	6.7449	1.8298
42	131.5		632	600	616.0		177			
	126.0		600	672	636.0		166			
	129.0		653	584	618.5		166			
	128.0		600	616	608.0		166			
	127.5		661	618	639.5		158			
	124.5		590	641	615.5		166			
	129.5		653	588	620.5		165			
	129.5		581	621	601.0		151			
	127.5		665	615	640.0		152			
	128.5		610	668	639.0		160			
Mean	128.2	431.6			623.4	2906.3	162.7	758.5	6.7337	1.7574

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
43	131.5		651	605	628.0		158			
	131.0		608	647	627.5		150			
	131.0		640	594	617.0		155			
	131.0		620	638	629.0		150			
	121.0		604	600	602.0		168			
	133.0		594	620	607.0		160			
	131.0		600	572	586.0		167			
	131.0		607	641	624.0		150			
	131.0		623	652	637.5		169			
	131.0		639	627	633.0		158			
Mean	131.3	442.1			619.1	2886.2	158.5	738.9	6.5283	1.6713
44	132.5		600	618	609.0		173			
	132.5		655	643	649.0		171			
	133.0		653	650	651.5		179			
	130.0		630	600	615.0		168			
	132.5		615	646	630.5		162			
	132.5		656	618	637.0		163			
	133.5		676	611	643.5		179			
	133.0		594	651	622.5		155			
	132.5		666	639	652.5		158			
	130.5		588	656	622.0		154			
Mean	132.3	445.5			633.3	2952.4	166.2	774.8	6.6271	1.7391

45	127.0		665	690	677.5		192			
	128.0		686	630	658.0		180			
	126.5		685	722	703.5		192			
	127.0		705	685	695.0		182			
	126.5		705	683	699.0		191			
	128.5		724	680	702.0		184			
	125.0		685	700	692.5		179			
	128.0		714	651	682.5		184			
	127.5		664	705	684.5		182			
	127.0		636	600	618.0		177			
Mean	127.1	446.2			681.3	3176.2	184.3	859.2	7.1183	1.9255
46	146.5		726	667	696.5		164			
	146.0		712	760	736.0		170			
	147.5		727	738	732.5		163			
	145.0		680	708	694.0		165			
	142.0		761	700	730.5		173			
	145.0		712	729	720.5		173			
	145.5		709	741	725.0		172			
	142.0		683	741	712.0		174			
	141.5		735	725	730.0		170			
	149.5		709	807	758.0		165			
Mean	145.1	488.6			723.5	3373.0	168.9	787.4	6.9033	1.6115
47	150.0		690	650	670.0		188			
	142.0		705	711	708.0		185			
	151.0		722	703	712.5		179			
	149.5		690	694	692.0		170			
	147.5		747	716	731.5		171			
	142.5		748	798	773.0		185			
	147.5		729	747	738.0		175			
	145.5		679	729	704.0		179			
	144.0		751	735	743.0		176			
	148.0		729	737	733.0		176			
Mean	145.8	490.9			720.5	3359.0	178.4	831.7	6.8425	1.6942

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
48	154.0		787	874	830.5		213			
	156.0		842	800	821.0		200			
	156.0		828	886	857.0		200			
	156.5		846	842	844.0		200			
	155.0		796	814	805.0		200			
	154.5		843	812	827.5		207			
	153.5		839	869	854.0		212			
	154.0		834	800	817.0		220			
	155.0		813	782	797.5		200			
	155.5		784	800	792.0		186			
Mean	155.0	544.1			824.6	3844.3	203.8	950.1	7.0654	1.7461
49	168.5		924	900	912.5		200			
	162.0		880	967	923.5		225			
	165.5		900	862	881.0		200			
	154.0		885	931	908.0		200			
	162.5		908	890	899.0		200			
	168.5		878	939	908.5		200			
	163.5		963	938	950.5		200			
	166.5		900	969	934.5		195			
	161.5		936	900	918.0		200			
	166.5		866	919	892.5		215			
Mean	163.9	551.9			912.8	4255.5	203.5	948.7	7.7106	1.7189

50	162.0		894	956	925.0		210			
	162.0		940	891	915.5		230			
	165.0		876	933	904.5		227			
	161.5		917	845	881.0		220			
	157.5		900	986	943.0		225			
	157.5		907	884	895.5		226			
	159.0		900	950	925.0		220			
	158.5		928	879	903.5		234			
	157.0		915	956	935.5		235			
	160.0		878	924	901.0		210			
Mean	160.0	561.7			913.0	4256.4	223.7	1042.9	7.5777	1.8566
51	170.0		922	900	911.0		184			
	169.0		894	848	871.0		181			
	173.0		885	805	845.0		200			
	167.0		891	935	913.0		200			
	166.0		865	822	843.5		200			
	171.0		831	851	841.0		200			
	169.0		900	944	922.0		200			
	171.0		836	831	833.5		200			
	171.0		880	896	888.0		200			
	169.5		905	875	890.0		200			
Mean	169.7	571.4			875.8	4083.0	196.5	916.1	7.1455	1.6032
52	173.0		965	1015	990.0		214			
	172.5		962	985	973.5		228			
	168.0		982	1009	995.5		213			
	170.5		1020	1000	1010.0		213			
	168.0		1002	1008	1005.0		200			
	173.0		1022	958	990.0		212			
	171.0		936	973	954.5		200			
	174.5		968	960	964.0		200			
	177.5		910	974	942.0		214			
	175.5		900	985	942.5		200			
Mean	172.4	580.5			976.7	4553.8	209.4	976.2	7.8446	1.6816

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
53	169.0		946	983	964.5		250			
	170.5		1027	950	988.5		227			
	172.0		971	1028	999.5		236			
	171.0		1029	964	996.5		241			
	172.0		1000	1022	1011.0		243			
	171.0		966	955	960.5		238			
	169.0		962	993	977.5		240			
	169.0		1048	1000	1024.0		241			
	168.0		1000	1030	1015.0		245			
	168.5		1030	962	996.0		250			
Mean	170.0	596.8			913.3	4257.8	241.1	1124.0	7.1343	1.8833
54	171.0		910	918	914.0		218			
	170.5		900	850	875.0		220			
	171.5		900	916	908.0		220			
	170.0		890	870	880.0		221			
	170.0		893	900	896.5		232			
	170.0		940	900	920.0		235			
	171.5		875	908	891.5		221			
	168.0		927	895	911.0		218			
	169.0		900	892	896.0		219			
	171.5		900	928	914.0		223			
Mean	170.3	597.8			900.6	4198.6	222.7	1038.2	7.0234	1.7367

55	175.0		984	982	983.0		200			
	172.5		993	975	984.0		200			
	176.5		963	989	976.0		207			
	180.5		1020	985	1002.5		200			
	182.0		955	1008	981.5		200			
	184.0		1008	1014	1011.0		207			
	182.5		973	993	983.0		200			
	180.0		1023	973	998.0		210			
	180.0		960	1000	980.0		214			
	180.0		1015	952	983.5		219			
Mean	179.3	603.7			988.3	4607.5	205.7	959.0	7.6321	1.5885
56	182.0		62	65	63.5		13			
	185.0		68	62	65.0		13			
	190.0		62	63	62.5		13			
	184.0		66	62	64.0		14			
	177.0		61	65	63.0		14			
	176.0		66	62	64.0		13			
	177.5		58	68	63.0		12			
	181.0		65	66	65.5		13			
	182.0		61	64	62.5		13			
	185.0		65	67	66.0		14			
Mean	182.0	638.9			63.9	4913.9	13.2	1015.1	7.6911	1.5888
57	199.5		60	60	60.0		16			
	199.0		59	64	61.5		15			
	204.0		66	65	65.5		15			
	194.0		62	66	64.0		15			
	196.0		67	62	64.5		16			
	202.0		60	66	63.0		16			
	196.0		61	59	60.0		16			
	196.5		62	68	65.0		15			
	199.0		68	61	64.5		15			
	204.0		63	67	65.0		15			
Mean	199.0	670.0			63.3	4867.8	15.4	1184.3	7.2653	1.7676

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
58	205.5		72	71	71.5		16			
	202.0		73	74	73.5		17			
	206.5		72	77	74.5		17			
	201.0		76	69	72.5		16			
	205.0		69	75	72.0		15			
	209.0		70	66	68.0		16			
	208.0		71	77	74.0		16			
	200.0		80	77	78.5		17			
	200.5		70	72	71.0		16			
	200.5		72	68	70.0		16			
Mean	203.8	715.4			72.6	5582.9	16.2	1245.8	7.8039	1.7414
59	227.0		82	84	83.0		17			
	235.5		87	82	84.5		18			
	223.0		83	89	85.5		18			
	232.0		83	77	80.0		18			
	226.5		86	90	88.0		20			
	226.0		84	78	81.0		17			
	227.0		82	85	83.5		19			
	228.0		83	79	81.0		18			
	232.0		79	80	79.5		18			
	232.0		82	89	85.5		19			
Mean	228.9	803.5			83.2	6398.1	18.2	1399.6	7.9627	1.7418

60	257.0		87	80	83.5		17			
	246.0		81	85	83.0		18			
	254.0		85	81	83.0		18			
	253.0		87	88	87.5		20			
	250.0		86	83	84.5		19			
	242.0		85	85	85.0		20			
	243.5		90	85	87.5		20			
	243.0		90	90	90.0		21			
	245.5		90	87	88.5		21			
	244.0		84	92	88.0		20			
Mean	247.8	834.3			86.1	6621.1	19.4	1491.9	7.9361	1.7882
61	249.5		98	95	96.5		21			
	258.0		100	98	99.0		21			
	250.5		96	96	96.0		21			
	254.0		95	93	94.0		21			
	255.5		93	93	93.0		21			
	256.5		100	102	101.0		22			
	254.0		99	94	96.5		21			
	256.5		96	99	97.5		21			
	258.5		100	95	97.5		21			
	263.0		93	99	96.0		21			
Mean	255.6	860.6			96.7	7436.2	21.1	1622.6	8.6407	1.8854

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:

1) For spherical drop measurements:
   a) Vickers Eyepiece #1 (10X objective), k = 1.7182 for Samples 1 to 3 and 6.
   b) Vickers Eyepiece #2 (5X objective), k = 3.5104 for Samples 4, 5, 7, 9 to 14, 17, 18, 36 to 38, 41, 45, 48, 50, 53, 54, 56, 58, and 59.
   c) Vickers Eyepiece #1 (5X objective), k = 3.367 for Samples 8, 15, 16, 19 to 35, 39, 40, 42 to 44, 46, 47, 49, 51, 52, 55, 57, 60, and 61.
2) For card spot measurements:
   a) 12.5X Filar Eyepiece (2X objective), k = 4.662 for Samples 1 to 55.
   b) Stereomicroscope (20X objective), k = 76.9 for Samples 56 to 60.

b. Spherical drop diameter divided into outer spot and center spot diameters, respectively.

APPENDIX III

13:1 STULL BIFLUID MIXING RATIO RAW DATA ANALYSIS

Sample No.	Spherical Drop Diameter		Outside Card Spot Diameter				Center Card Spot Diameter		Spread Factors[b]	
	Div.[a]	Microns	Divisions[a] Meas. 1	Meas. 2	Mean	Microns	Div.[a]	Microns	Outer Spot	Center Spot
1	45.0		131	127	129.0		42			
	43.5		134	129	131.5		59			
	43.5		131	133	132.0		55			
	42.0		147	139	143.0		65			
	41.5		131	140	135.5		51			
	42.5		134	140	137.0		57			
	44.5		149	143	146.0		57			
	43.0		137	141	139.0		57			
	41.5		143	140	141.5		52			
	42.5		143	149	146.0		52			
Mean	43.0	144.8			138.1	643.8	54.7	255.0	4.4461	1.7610
2	56.5		227	220	223.5		70			
	56.0		215	225	220.0		63			
	54.5		216	217	216.5		69			
	55.5		218	227	222.5		72			
	56.5		221	211	216.0		75			
	55.0		213	223	218.0		73			
	55.0		224	213	218.5		70			
	55.5		225	222	223.5		76			
	56.5		226	220	223.0		72			
	55.5		217	222	219.5		77			
Mean	55.7	187.5			220.1	1026.1	71.7	334.3	5.4725	1.7829

3	78.0		368	355	361.5		91			
	77.0		344	373	358.5		89			
	78.5		369	335	352.0		91			
	77.0		364	396	380.0		100			
	80.0		400	364	387.0		100			
	78.5		376	395	385.5		100			
	80.0		384	373	378.5		117			
	74.5		368	388	378.0		96			
	79.5		376	359	367.5		100			
	79.5		355	378	366.5		100			
Mean	78.3	263.6			371.5	1731.9	98.4	458.7	6.5701	1.7401
4	104.5		462	472	467.0		139			
	106.0		465	515	490.0		138			
	106.0		512	505	508.5		162			
	108.5		468	509	488.5		139			
	111.0		518	494	506.0		139			
	104.5		496	525	510.5		150			
	103.5		538	470	504.0		141			
	104.5		480	500	490.0		168			
	106.5		500	488	494.0		148			
	106.0		500	496	498.0		158			
Mean	106.1	357.2			495.7	2311.0	148.2	690.9	6.4697	1.9342

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
5	136.0		640	700	670.0		164			
	138.5		727	673	700.0		176			
	133.5		658	730	694.0		172			
	135.0		700	682	691.0		177			
	139.0		671	746	708.5		171			
	132.5		785	679	732.0		166			
	140.0		658	678	668.0		165			
	135.5		732	719	725.5		163			
	134.5		708	739	723.5		158			
	135.0		700	687	693.5		164			
Mean	136.0	457.9			700.6	3266.2	167.6	781.4	7.1329	1.7064
6	154.0		846	751	798.5		187			
	156.5		772	791	781.5		220			
	155.5		822	749	785.5		217			
	154.5		772	847	809.5		211			
	150.0		775	748	761.5		231			
	153.0		747	778	762.5		192			
	154.0		829	767	798.0		228			
	155.5		773	800	786.5		164			
	151.0		815	786	800.5		200			
	156.0		754	716	735.0		205			
Mean	154.1	518.9			781.9	3645.2	205.5	958.0	7.0248	1.8462

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
1) For spherical drop measurements, Vickers Eyepiece #2 (5X objective), k = 3.367 for all samples.
2) For card spot measurements, 12.5X Filar Eyepiece (2X objective), k = 4.662 for all samples.

b. Spherical drop diameter divided into outer spot and center spot diameters, respectively.

APPENDIX IV

17:1 STULL BIFLUID MIXING RATIO RAW DATA ANALYSIS

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions[a] Meas. 1	Meas. 2	Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
1	45.5		157	153	155.0		63			
	46.0		167	161	164.0		68			
	45.5		162	168	165.0		58			
	45.0		161	154	157.5		60			
	47.0		156	153	154.5		51			
	47.0		168	165	166.5		56			
	47.0		165	164	164.5		61			
	46.0		157	166	161.5		65			
	45.5		162	170	166.0		62			
	45.5		167	172	169.5		64			
Mean	46.0	154.9			162.4	757.1	60.8	283.4	4.8876	1.8295
2	62.5		270	250	260.0		82			
	60.5		254	269	261.5		90			
	61.0		261	261	261.0		90			
	62.0		265	268	266.5		94			
	61.5		261	244	252.5		90			
	62.5		263	265	264.0		93			
	61.0		264	266	265.0		91			
	61.5		264	261	262.5		86			
	60.0		263	251	257.0		88			
	60.5		253	250	251.5		91			
Mean	61.3	206.4			260.2	1213.1	89.5	417.2	5.8774	2.0213

V.75

Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Outside Card Spot Diameter Divisions Meas. 1	Outside Card Spot Diameter Divisions Meas. 2	Outside Card Spot Diameter Divisions Mean	Outside Card Spot Diameter Microns	Center Card Spot Diameter Div.[a]	Center Card Spot Diameter Microns	Spread Factors[b] Outer Spot	Spread Factors[b] Center Spot
3	82.0		378	367	372.5		115			
	86.0		375	360	367.5		116			
	82.5		368	372	370.0		116			
	83.5		373	363	368.0		108			
	83.5		380	367	368.5		115			
	83.0		340	349	344.5		108			
	84.0		371	353	362.0		107			
	81.0		362	368	365.0		107			
	83.0		374	340	357.5		114			
	85.0		364	370	367.0		100			
Mean	83.4	280.8			364.3	1698.4	110.6	515.6	6.0484	1.8361
4	122.0		596	550	573.0		177			
	123.0		552	590	571.0		180			
	123.5		558	527	542.5		182			
	119.5		585	592	588.5		170			
	116.5		605	559	582.0		183			
	123.0		559	583	571.0		181			
	122.0		580	560	570.0		179			
	120.5		550	573	561.5		172			
	120.0		603	550	576.5		160			
	121.5		541	581	561.0		179			
Mean	121.2	408.1			569.7	2655.9	176.3	821.9	6.5079	2.0139

5	137.0		725	746	735.5		200			
	135.5		752	692	722.0		200			
	142.0		640	694	667.0		200			
	140.5		690	662	676.0		192			
	137.5		677	716	696.5		162			
	133.0		788	690	739.0		200			
	142.0		663	711	687.0		200			
	139.5		710	660	685.0		200			
	141.5		658	768	713.0		216			
	136.5		668	639	653.5		177			
Mean	138.5	466.3			697.5	3251.7	194.7	907.7	6.9734	1.9466
6	184.5		910	906	908.0		232			
	182.0		963	915	939.0		239			
	188.0		911	922	916.5		240			
	186.0		922	905	913.5		230			
	183.0		937	911	924.0		237			
	182.5		900	923	911.5		249			
	185.0		918	925	921.5		249			
	184.0		919	930	924.5		233			
	180.5		888	851	869.5		240			
	184.0		920	945	932.5		230			
Mean	184.0	619.5			916.1	4270.9	237.9	1109.1	6.8941	1.7903

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
1) For spherical drop measurements, Vickers Eyepiece #2 (5X objective), k = 3.367 for all samples.
2) For card spot measurements, 12.5X Filar Eyepiece (2X objective), k = 4.662 for all samples.

b. Spherical drop diameter divided into outer spot and center spot diameters, respectively.

APPENDIX V

RED KIDNEY BEAN LEAF RAW DATA ANALYSIS

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter						Spread Factor[b]		
				Day 1		Day 2		Day 3				
		Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2	Day 3
ORANGE	1-1			30		36		32				
				40		44		39				
				39		39		40				
				55		37		38				
				43		33		32				
				41		35		33				
				43		33		40				
				34		32		34				
				33		37		37				
				37		32		36				
	Mean	36.0	126.0	39.5	187.2	35.8	169.7	35.1	166.3	1.4857	1.3468	1.3198
Bifluid	1-1			33		40		57				
				37		39		49				
				42		31		46				
				38		38		35				
				36		43		45				
				39		44		43				
				39		47		44				
				40		32		40				
				37		47		44				
				36		45		40				
	Mean	36.2	122.0	37.7	178.7	40.6	192.4	44.3	209.9	1.4648	1.5770	1.7204

ORANGE	1-2			30		35		43				
				38		38		33				
				35		31		33				
				34		38		42				
				40		30		28				
				41		40		35				
				40		32		42				
				39		35		36				
				33		33		28				
				36		36		25				
	Mean	36.0	126.0	36.6	173.4	34.8	164.9	34.5	163.5	1.3762	1.3087	1.2916
Bifluid	1-2			37		45		41				
				40		45		36				
				33		46		46				
				35		32		45				
				40		36		48				
				37		35		45				
				42		36		47				
				39		37		49				
				39		42		48				
				35		30		45				
	Mean	36.2	122.0	37.7	178.7	38.4	182.0	45.0	213.3	1.4648	1.4918	1.7483
ORANGE	1-3			33		36		37				
				37		40		36				
				42		33		40				
				38		39		37				
				36		40		38				
				39		43		37				
				39		30		36				
				40		37		39				
				37		40		40				
				36		39		31				
	Mean	36.0	126.0	38.6	182.9	37.7	178.7	37.1	175.8	1.4516	1.4182	1.3952

		Spherical Drop Diameter		Leaf Spot Diameter Day 1		Leaf Spot Diameter Day 2		Leaf Spot Diameter Day 3		Spread Factor[b]		
Agent	Sample No.	Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2	Day 3
Bifluid	1-3			34		45		35				
				40		49		53				
				38		46		42				
				40		45		53				
				37		43		43				
				32		43		36				
				33		46		39				
				33		40		42				
				39		38		36				
				38		46		40				
	Mean	36.2	122.0	36.4	172.5	44.1	209.0	41.9	198.6	1.4139	1.7131	1.6278
ORANGE	1-4			37		39		31				
				34		34		33				
				39		37		36				
				35		36		42				
				41		39		39				
				31		40		40				
				37		34		40				
				44		37		35				
				35		40		36				
				36		42		41				
	Mean	36.0	126.0	36.9	174.9	37.8	179.1	37.3	176.8	1.3881	1.4214	1.4031

Bifluid	1-4			41		35		37				
				37		31		40				
				39		36		40				
				36		35		39				
				33		38		36				
				43		36		42				
				33		37		37				
				38		43		29				
				42		36		35				
				40		36		36				
	Mean	36.2	122.0	38.2	181.0	36.3	172.0	37.1	175.8	1.4836	1.4098	1.4409
ORANGE	2-1			80		87		85				
				80		91		79				
				84		92		90				
				78		87		91				
				87		91		90				
				83		90		89				
				90		93		96				
				84		88		91				
				75		93		93				
				84		78		88				
	Mean	76.0	267.0	82.5	391.0	89.0	421.8	89.2	422.7	1.4644	1.5797	1.5831
Bifluid	2-1			81		113		100				
				92		109		100				
				76		104		100				
				93		94		97				
				83		90		76				
				93		93		83				
				87		96		93				
				95		95		89				
				90		100		92				
				92		75		106				
	Mean	79.4	267.3	88.2	418.0	96.9	459.2	93.6	443.6	1.5637	1.7179	1.6595

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter						Spread Factor[b]		
				Day 1		Day 2		Day 3				
		Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2	Day 3
ORANGE	2-2			78		94		94				
				80		106		100				
				84		89		81				
				79		83		94				
				90		82		90				
				96		97		90				
				88		96		89				
				93		97		94				
				93		83		91				
				92		106		93				
	Mean	76.0	267.0	87.3	413.7	93.3	442.1	91.6	434.1	1.5494	1.6558	1.6258
Bifluid	2-2			90		95		100				
				95		87		113				
				88		96		96				
				83		92		87				
				81		105		75				
				82		87		100				
				94		110		92				
				93		100		100				
				88		91		100				
				79		95		92				
	Mean	79.4	267.3	87.3	413.7	95.8	454.0	95.5	452.6	1.5476	1.6984	1.6932

ORANGE	2-3			85		87		83				
				89		85		81				
				80		85		93				
				95		95		87				
				79		95		85				
				92		91		74				
				81		94		100				
				85		100		93				
				92		89		97				
				90		92		96				
	Mean	76.0	267.0	86.8	411.3	91.3	432.7	88.9	421.3	1.5404	1.6205	1.5779
Bifluid	2-3			91		100		117				
				93		87		100				
				81		120		113				
				92		96		94				
				93		119		90				
				81		89		100				
				82		95		100				
				94		106		100				
				96		112		109				
				97		115		120				
	Mean	79.4	267.3	90.0	426.5	103.9	492.4	104.3	494.3	1.5955	1.8421	1.8492
ORANGE	3-1			180		216		173				
				179		190		200				
				183		185		162				
				182		180		179				
				175		218		173				
				184		150		187				
				190		206		170				
				184		172		193				
				166		186		186				
				176		166		-				
	Mean	143.0	502.0	179.9	852.5	186.9	885.7	180.3	854.4	1.6982	1.7643	1.7019

		Spherical Drop Diameter		Leaf Spot Diameter								
				Day 1		Day 2		Day 3		Spread Factor[b/]		
Agent	Sample No.	Div.[a/]	Microns	Div.[a/]	Microns	Div.[a/]	Microns	Div.[a/]	Microns	Day 1	Day 2	Day 3
Bifluid	3-1			155		294		207				
				172		209		248				
				167		208		200				
				177		200		194				
				175		225		173				
				170		168		175				
				175		210		220				
				185		-		-				
				154		-		-				
				168		-		-				
	Mean	146.2	491.0	169.8	804.7	216.3	1025.0	188.1	891.4	1.6389	2.0875	1.8154
ORANGE	3-2			165		213		183				
				184		182		196				
				192		168		231				
				176		190		178				
				178		189		171				
				178		236		186				
				184		157		195				
				178		200		244				
				165		190		200				
				158		216		187				
	Mean	143.0	502.0	175.8	833.1	194.1	919.8	197.1	934.1	1.6595	1.8322	1.8607

Bifluid	3-2				184		191		238				
					192		190		192				
					163		188		187				
					173		249		237				
					188		230		218				
					170		197		170				
					169		190		235				
					182		226		200				
					170		200		192				
					186		231		212				
		Mean	146.2	491.0	177.7	842.1	209.2	991.4	208.1	986.2	1.7150	2.0191	2.0085
ORANGE	3-3				170		215		214				
					194		182		190				
					165		157		195				
					153		178		213				
					190		200		189				
					177		196		200				
					200		155		157				
					157		183		142				
					180		183		179				
					190		200		180				
		Mean	143.0	502.0	177.6	841.6	184.9	876.2	185.9	881.0	1.6764	1.7454	1.7549

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Leaf Spot Diameter Day 3 Div.[a]	Leaf Spot Diameter Day 3 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2	Spread Factor[b] Day 3
Bifluid	3-3			167		165		192				
				177		168		194				
				184		191		200				
				188		163		164				
				175		155		175				
				174		197		165				
				169		145		147				
				178		222		209				
				162		194		214				
				156		225		200				
	Mean	146.2	491.0	173.0	819.8	182.5	864.9	186.0	881.5	1.6696	1.7615	1.7953

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
   1) For spherical drop measurements:
      a) Vickers Eyepiece #1 (5X objective), k = 3.5104 for all ORANGE samples.
      b) Vickers Eyepiece #2 (5X objective), k = 3.367 for all Bifluid samples.
   2) For leaf spot measurements, 12.5X Filar Eyepiece #1 (2X objective), k = 4.739 for all samples.

b. Spherical drop diameter divided into leaf spot diameters.

APPENDIX VI

BLACK VALENTINE BEAN PLANT RAW DATA ANALYSIS

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2
ORANGE	1-1	140.5		209		200			
		140.5		167		212			
		140.5		209		218			
		140.5		180		233			
		140.5		179		200			
		140.5		192		200			
		140.5		206		191			
		140.5		181		160			
		140.5		183		187			
		140.5		193		180			
	Mean	140.5	493.2	189.9	899.9	198.1	938.8	1.8246	1.9034
Bifluid	1-1	150.5		188		200			
		147.0		175		180			
		144.5		173		140			
		146.5		183		207			
		152.0		167		200			
		145.0		184		200			
		142.5		186		191			
		143.5		164		175			
		146.0		165		213			
		152.5		177		212			
	Mean	147.0	494.9	176.2	835.0	191.8	908.9	1.6872	1.8365

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2
ORANGE	1-2	140.5		187		208			
		140.5		196		200			
		140.5		170		194			
		140.5		200		190			
		140.5		180		196			
		140.5		186		197			
		140.5		152		176			
		140.5		189		174			
		140.5		194		225			
		140.5		194		200			
	Mean	140.5	493.2	184.8	875.8	196.0	928.8	1.7757	1.8832
Bifluid	1-2	150.5		171		227			
		147.0		174		177			
		144.5		175		153			
		146.5		182		180			
		152.0		185		217			
		145.0		182		168			
		142.5		187		193			
		143.5		185		140			
		146.0		197		217			
		152.5		183		236			
	Mean	147.0	494.9	182.1	863.0	190.8	904.2	1.7437	1.8270

ORANGE	1-3	140.5		173		213			
		140.5		186		177			
		140.5		179		158			
		140.5		154		173			
		140.5		169		162			
		140.5		178					
		140.5		210					
		140.5		200					
		140.5		204					
		140.5		190					
	Mean	140.5	493.2	184.3	873.4	176.6	836.9	1.7708	1.6968
Bifluid	1-3	150.5		174		213			
		147.0		188		200			
		144.5		182		212			
		146.5		163		181			
		152.0		184		181			
		145.0		176		175			
		142.5		193		183			
		143.5		179		190			
		146.0		179		147			
		152.5		179		195			
	Mean	147.0	494.9	179.7	851.6	187.7	889.5	1.7207	1.7973
ORANGE	2-1	74.0		95		91			
		74.0		90		83			
		74.0		90		100			
		74.0		73		100			
		74.0		82		88			
		73.0		90		97			
		75.0		80		84			
		74.0		89		110			
		74.0		82		97			
		74.0		84		92			
	Mean	74.0	259.8	85.5	405.2	92.6	438.8	1.5596	1.6889

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b/]	
				Day 1		Day 2			
		Div.[a/]	Microns	Div.[a/]	Microns	Div.[a/]	Microns	Day 1	Day 2
Bifluid	2-1	78.5		90		100			
		79.5		110		81			
		77.5		96		100			
		80.5		96		105			
		78.5		93		112			
		79.0		100		105			
		77.0		92		106			
		78.0		82		112			
		77.0		89		113			
		78.0		96		112			
	Mean	78.4	264.0	94.4	447.4	104.6	495.7	1.6946	1.8776
ORANGE	2-2	74.0		95		107			
		74.0		84		86			
		74.0		92		83			
		74.0		97		100			
		74.0		81		89			
		73.0		91		81			
		75.0		84		87			
		74.0		87		92			
		74.0		89					
		74.0		78					
	Mean	74.0	259.8	87.8	416.1	90.6	429.4	1.6061	1.6528

Bifluid	2-2	78.5		92		108			
		79.5		88		89			
		77.5		95		74			
		80.5		109		100			
		78.5		90		83			
		79.0		108					
		77.0		82					
		78.0		84					
		77.0		107					
		78.0		93					
	Mean	78.4	264.0	94.8	449.3	90.8	430.3	1.7018	1.6299
ORANGE	2-3	74.0		92		100			
		74.0		98		85			
		74.0		81		85			
		74.0		93		88			
		74.0		87		91			
		73.0		87		93			
		75.0		85		89			
		74.0		80		100			
		74.0		89		94			
		74.0		95		88			
	Mean	74.0	259.8	88.7	420.3	91.3	432.7	1.6177	1.6655
Bifluid	2-3	77.0		75		100			
		78.5		87		84			
		79.5		100		82			
		77.5		85		83			
		80.5		92		64			
		78.5		80		77			
		79.0		84		83			
		77.0		91		78			
		77.0		97		71			
		78.0		102		75			
	Mean	78.4	264.0	89.3	423.2	79.7	377.8	1.6030	1.4310

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b/]	
				Day 1		Day 2			
		Div.[a/]	Microns	Div.[a/]	Microns	Div.[a/]	Microns	Day 1	Day 2
ORANGE	3-1	31.5		47		43			
		31.5		36		36			
		31.5		38		49			
		31.5		36		39			
		31.5		42		42			
		31.5		40		45			
		31.5		34		38			
		31.5		43		46			
		31.5		38		38			
		31.5		43		37			
	Mean	31.5	110.6	39.7	188.1	41.3	195.7	1.7007	1.7694
Bifluid	3-1	34.0		43		42			
		33.5		39		40			
		32.5		33		34			
		33.0		38		31			
		32.5		43		41			
		33.0		42		28			
		33.0		39		36			
		33.0		43		38			
		33.5		34		36			
		32.5		35		40			
	Mean	33.1	111.4	38.9	184.3	36.6	173.4	1.6543	1.5565

ORANGE	3-2	31.5		45		45			
		31.5		36		45			
		31.5		34		41			
		31.5		45		43			
		31.5		40		45			
		31.5		47		38			
		31.5		43		48			
		31.5		48		46			
		31.5		46		42			
		31.5		30		43			
	Mean	31.5	110.6	41.4	196.2	43.6	206.6	1.7739	1.8679
Bifluid	3-2	34.0		33		37			
		33.5		37		42			
		32.5		34		40			
		33.0		42		48			
		32.5		35		36			
		33.0		34		45			
		33.0		37		38			
		33.0		36		40			
		33.5		38		27			
		32.5		34		39			
	Mean	33.1	111.4	36.0	170.6	39.2	185.8	1.5314	1.6678
ORANGE	3-3	31.5		35		29			
		31.5		34		28			
		31.5		36		30			
		31.5		32		26			
		31.5		33		38			
		31.5		28		27			
		31.5		30		30			
		31.5		28		23			
		31.5		25		25			
		31.5		28		33			
	Mean	31.5	110.6	30.9	146.4	28.9	137.0	1.3236	1.2386

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2
Bifluid	3-3	34.0		32		29			
		33.5		28		40			
		32.5		34		33			
		33.0		39		37			
		32.5		30		31			
		33.0		33		36			
		33.0		34		25			
		33.0		35		20			
		33.5		35		27			
		32.5		36		29			
	Mean	33.1	111.4	33.6	159.2	30.7	145.5	1.4290	1.3061

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
   1) For spherical drop measurements:
      a) Vickers Eyepiece #1 (5X objective), k = 3.5104 for all ORANGE samples.
      b) Vickers Eyepiece #2 (5X objective), k = 3.367 for all Bifluid samples.
   2) For leaf spot measurements, 12.5X Filar Eyepiece #1 (2X objective), k = 4.739 for all samples.

b. Spherical drop diameter divided into leaf spot diameters.

APPENDIX VII

SILVER MAPLE LEAF RAW DATA ANALYSIS

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter on Day 3 Div.[a]	Leaf Spot Diameter on Day 3 Microns	Spread Factor[b]
ORANGE	1-1			48		
				52		
				43		
				40		
				45		
				50		
				45		
				46		
				57		
				51		
	Mean	39.0	137	47.7	233.8	1.7065
Bifluid	1-1			61		
				52		
				57		
				42		
				56		
				53		
				47		
				63		
				42		
				45		
	Mean	41.6	140	51.8	253.9	1.8135
ORANGE	1-2			37		
				53		
				36		
				34		
				60		
				44		
				41		
				39		
				40		
				46		
	Mean	39.0	137	43.0	210.7	1.5379
Bifluid	1-2			48		
				60		
				47		
				45		
				50		
				52		
				56		
				57		
				45		
				42		
	Mean	41.6	140	50.2	246.0	1.7571

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter on Day 3 Div.[a]	Leaf Spot Diameter on Day 3 Microns	Spread Factor[b]
ORANGE	1-3			39		
				40		
				39		
				37		
				33		
				61		
				41		
				39		
				34		
				38		
	Mean	39.0	137	41.1	201.4	1.4700
Bifluid	1-3			43		
				34		
				48		
				36		
				42		
				50		
				40		
				41		
				42		
				63		
	Mean	41.6	140	43.9	215.2	1.5371
ORANGE	2-1			84		
				104		
				91		
				105		
				96		
				98		
				97		
				101		
				105		
				100		
	Mean	71.5	251	98.1	480.8	1.9155
Bifluid	2-1			106		
				137		
				97		
				106		
				112		
				124		
				136		
				134		
				131		
				114		
	Mean	70.5	237	119.7	586.6	2.4751

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Microns	Leaf Spot Diameter on Day 3 Div.[a]	Microns	Spread Factor[b]
ORANGE	2-2			143		
				111		
				115		
				94		
				99		
				111		
				91		
				92		
				94		
				129		
	Mean	71.5	251	107.9	528.8	2.1067
Bifluid	2-2			93		
				95		
				96		
				80		
				110		
				109		
				88		
				89		
				98		
				86		
	Mean	70.5	237	94.4	462.7	1.9523
ORANGE	2-3			80		
				97		
				88		
				90		
				106		
				88		
				95		
				81		
				75		
				94		
	Mean	71.5	251	89.4	438.1	1.7454
Bifluid	2-3			92		
				95		
				94		
				92		
				85		
				106		
				104		
				106		
				98		
				78		
	Mean	70.5	237	95	465.6	1.9645

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Microns	Leaf Spot Diameter on Day 3 Div.[a]	Microns	Spread Factor[b]
ORANGE	3-1			133		
				174		
				188		
				190		
				192		
				208		
				222		
				209		
				220		
				222		
	Mean	142.0	498	195.8	959.6	1.9269
Bifluid	3-1			200		
				192		
				212		
				177		
				158		
				194		
				178		
				206		
				149		
				190		
	Mean	147.3	496	185.6	909.6	1.8338
ORANGE	3-2			318		
				190		
				186		
				275		
				268		
				284		
				218		
				255		
				273		
				256		
	Mean	142.0	498	252.2	1236.5	2.4829
Bifluid	3-2			279		
				93		
				120		
				232		
				148		
				200		
				250		
				208		
				188		
				140		
	Mean	147.3	496	185.8	910.6	1.8358

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter on Day 3		Spread Factor[b]
		Div.[a]	Microns	Div.[a]	Microns	
ORANGE	3-3			252		
				160		
				240		
				229		
				280		
				200		
				214		
				256		
				240		
				176		
	Mean	142.0	498	224.7	1101.3	2.2114
Bifluid	3-3			200		
				175		
				200		
				195		
				188		
				227		
				211		
				225		
				188		
				226		
	Mean	147.3	496	203.5	997.4	2.0108

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
   1) For spherical drop measurements:
      a) Vickers Eyepiece #1 (5X objective), k = 3.5104 for all ORANGE samples.
      b) Vickers Eyepiece #2 (5X objective), k = 3.367 for all Bifluid samples.
   2) For leaf spot measurements, 12.5X Filar Eyepiece #2 (2X objective), k = 4.901 for all samples.

b. Spherical drop diameter divided into leaf spot diameter.

APPENDIX VIII

GREEN ASH TREE RAW DATA ANALYSIS

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2
ORANGE	1-1	142.5		165		192			
		142.5		196		186			
		142.5		172		197			
		142.5		200		194			
		142.5		192		219			
		142.5		200		182			
		142.5		209		210			
		142.5		180		165			
		142.5		180		179			
		142.5		185		184			
	Mean	142.5	500.2	187.9	890.5	190.8	935.1	1.7802	1.8694
Bifluid	1-1	155.5		192		178			
		155.0		200		218			
		152.5		188		160			
		155.5		175		174			
		158.0		182		188			
		155.0		194		222			
		153.5		191		167			
		157.0		170		198			
		156.0		184		207			
		154.5		182		189			
	Mean	155.3	522.9	185.8	880.5	190.1	931.7	1.6838	1.7824
ORANGE	1-2	142.5		215		186			
		142.5		235		189			
		142.5		212		228			
		142.5		230		187			
		142.5		181		194			
		142.5		220		196			
		142.5		211		189			
		142.5		217		186			
		142.5		200		180			
		142.5		176		178			
	Mean	142.5	500.2	209.7	993.8	191.3	937.6	1.9868	1.8744

Bifluid	1-2	155.5		200		220			
		155.0		175		212			
		152.5		188		190			
		155.5		186		192			
		158.0		179		180			
		155.0		170		183			
		153.5		178		168			
		157.0		179		166			
		156.0		185		194			
		154.5		192		185			
	Mean	155.3	522.9	183.2	868.2	189.0	926.3	1.6603	1.7721
ORANGE	1-3	142.5		217		252			
		142.5		189		238			
		142.5		196		177			
		142.5		213		188			
		142.5		217		204			
		142.5		238		248			
		142.5		234		169			
		142.5		237		240			
		142.5		176		243			
		142.5		182		158			
	Mean	142.5	500.2	209.9	994.7	211.7	1037.5	1.9886	2.0741
Bifluid	1-3	155.5		242		218			
		155.0		230		196			
		152.5		209		222			
		155.6		196		196			
		158.0		220		270			
		155.0		184		248			
		153.5		243		180			
		157.0		179		220			
		156.0		200		243			
		154.5		263		218			
	Mean	155.3	522.9	216.6	1026.5	221.1	1083.6	1.9630	2.0722

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b/]	
				Day 1		Day 2			
		Div.[a/]	Microns	Div.[a/]	Microns	Div.[a/]	Microns	Day 1	Day 2
ORANGE	2-1	73.0		88		96			
		73.0		79		94			
		73.0		63		85			
		73.0		86		92			
		73.0		92		92			
		73.0		87		93			
		73.0		88		93			
		73.0		82		98			
		73.0		91		91			
		73.0		85		85			
	Mean	73.0	256.3	84.1	412.2	91.9	435.5	1.6082	1.6991
Bifluid	2-1	77.0		81		111			
		76.0		94		100			
		77.5		89		94			
		77.5		96		100			
		75.5		85		106			
		78.0		91		97			
		76.0		89		112			
		79.5		93		100			
		79.0		94		104			
		79.0		86		100			
	Mean	77.7	261.6	89.8	440.1	102.4	485.3	1.6823	1.8551
ORANGE	2-2	73.0		74		78			
		73.0		83		80			
		73.0		76		100			
		73.0		86		89			
		73.0		80		84			
		73.0		73		88			
		73.0		71		106			
		73.0		82		67			
		73.0		76		92			
		73.0		77		95			
	Mean	73.0	256.3	77.8	381.3	87.9	416.6	1.4877	1.6254

Bifluid	2-2	77.0		84		141			
		76.0		82		141			
		77.5		76		113			
		77.5		84		134			
		75.5		78		113			
		78.0		87		168			
		76.0		80		114			
		79.5		85		122			
		79.0		91		104			
		79.0		94		100			
	Mean	77.7	261.6	84.1	412.2	125.0	592.4	1.5756	2.2645
ORANGE	2-3	73.0		79		100			
		73.0		98		92			
		73.0		81		90			
		73.0		77		96			
		73.0		82		97			
		73.0		87		108			
		73.0		91		80			
		73.0		85		81			
		73.0		94		98			
		73.0		91		100			
	Mean	73.0	256.3	86.5	423.9	94.2	446.4	1.6539	1.7417
Bifluid	2-3	77.0		90		137			
		76.0		84		122			
		77.5		88		100			
		77.5		82		106			
		75.5		92		109			
		78.0		84		105			
		76.0		86		106			
		79.5		90		111			
		79.0		98		100			
		79.0		92		102			
	Mean	77.7	261.6	88.6	434.2	109.8	520.3	1.6597	1.9889

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2
ORANGE	3-1	41.5		49		42			
		41.5		60		42			
		40.5		48		45			
		42.5		46		41			
		40.5		41		42			
		41.5		40		45			
		41.5		63		44			
		41.5		43		42			
		41.5		46		49			
		41.5		49		47			
	Mean	41.4	145.3	48.5	229.8	43.9	208.0	1.5815	1.4315
Bifluid	3-1	46.0		56		59			
		47.5		56		65			
		44.5		55		54			
		48.5		57		54			
		45.0		57		62			
		48.0		55		66			
		45.5		63		61			
		46.5		64		58			
		46.5		49		65			
		48.0		65		66			
	Mean	46.6	156.9	57.7	273.4	61.0	289.1	1.7425	1.8425

ORANGE	3-2	41.5		54		64			
		41.5		63		55			
		40.5		47		58			
		42.5		43		49			
		40.5		53		52			
		41.5		53		50			
		41.5		57		60			
		41.5		67		50			
		41.5		58		62			
		41.5		55		52			
	Mean	41.4	145.3	55.0	260.6	55.2	261.6	1.7935	1.8004
Bifluid	3-2	46.0		60		66			
		47.5		58		54			
		44.5		58		60			
		48.5		54		54			
		45.0		52		62			
		48.0		57		56			
		45.5		53		62			
		46.5		58		67			
		46.5		56		69			
		48.0		56		59			
	Mean	46.6	156.9	56.2	266.3	60.9	288.6	1.6972	1.8393
ORANGE	3-3	41.5		46		58			
		41.5		47		47			
		40.5		43		48			
		42.5		47		47			
		40.5		55		49			
		41.5		44		42			
		41.5		41		48			
		41.5		51		53			
		41.5		48		47			
		41.5		48		51			
	Mean	41.4	145.3	47.0	222.7	49.0	232.2	1.5326	1.5980

		Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b]	
				Day 1		Day 2			
Agent	Sample No.	Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2
Bifluid	3-3	46.0		53		57			
		47.5		59		53			
		44.5		52		55			
		48.5		53		56			
		45.0		56		53			
		48.0		61		57			
		45.5		57		52			
		46.5		61		53			
		46.5		58		57			
		48.0		57		52			
	Mean	46.6	156.9	56.7	268.7	54.5	258.3	1.7125	1.6462

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
   1) For spherical drop measurements:
      a) Vickers Eyepiece #1 (5X objective), k = 3.5104 for all ORANGE samples.
      b) Vickers Eyepiece #2 (5X objective), k = 3.367 for all Bifluid samples.
   2) For leaf spot measurements:
      a) 12.5X Filar Eyepiece #2 (2X objective), k = 4.901 for Sample 2, Day 1, and Sample 1, Day 2.
      b) 12.5X Filar Eyepiece #1 (2X objective), k = 4.739 for all other samples.

b. Spherical drop diameters divided into leaf spot diameters.

APPENDIX IX

DWARF BRUSH CHERRY RAW DATA ANALYSIS

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2
ORANGE	1-1	142.0		166		174			
		142.0		168		168			
		142.0		149		161			
		142.0		171		141			
		141.0		173		179			
		141.0		156		181			
		141.0		183		185			
		142.0		176		160			
		142.0		182		180			
		141.5		164		189			
	Mean	141.7	497.4	168.8	827.3	171.8	842.0	1.6632	1.6928
Bifluid	1-1	140.5		196		156			
		140.5		193		192			
		140.5		149		181			
		137.0		153		157			
		136.5		179		181			
		135.0		203		189			
		138.0		220		171			
		137.5		182		175			
		138.5		186		150			
		137.5		160		177			
	Mean	138.5	465.3	182.1	892.5	172.9	847.9	1.9181	1.8223

		Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b/]	
				Day 1		Day 2			
Agent	Sample No.	Div.[a/]	Microns	Div.[a/]	Microns	Div.[a/]	Microns	Day 1	Day 2
ORANGE	1-2	142.0		190		182			
		142.0		170		180			
		142.0		161		185			
		142.0		165		178			
		141.0		184		191			
		141.0		175		176			
		141.0		177		152			
		142.0		184		188			
		142.0		164		184			
		141.5		172		189			
	Mean	141.7	497.4	174.2	853.8	180.5	884.6	1.7165	1.7784
Bifluid	1-2	140.5		147		180			
		140.5		141		171			
		140.5		169		175			
		137.0		155		132			
		136.5		179		144			
		135.0		168		167			
		138.0		160		168			
		137.5		164		166			
		138.5		173		149			
		137.5		167		159			
	Mean	138.2	465.3	162.3	795.4	161.1	789.6	1.7094	1.6970

ORANGE	1-3	142.0		189		186			
		142.0		179		159			
		142.0		187		195			
		142.0		180		181			
		141.0		178		192			
		141.0		158		182			
		141.0		173		184			
		142.0		166		190			
		142.0		180		182			
		141.5		164		175			
	Mean	141.7	497.4	175.4	859.6	182.6	894.9	1.7281	1.7992
Bifluid	1-3	140.5		158		171			
		140.5		169		160			
		140.5		176		188			
		137.0		180		181			
		136.5		167		178			
		135.0		163		192			
		138.0		149		164			
		137.5		168		186			
		138.5		166		173			
		137.5		184		146			
	Mean	138.2	465.3	168.0	823.4	173.9	852.3	1.7696	1.8317
ORANGE	2-1	73.0		82		100			
		73.0		92		114			
		73.0		86		94			
		73.0		85		97			
		73.0		85		94			
		73.0		86		97			
		73.0		87		100			
		73.0		88		100			
		73.0		82		91			
		73.0		82		107			
	Mean	73.0	256.3	85.5	405.2	99.4	471.1	1.5809	1.8380

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b]	
				Day 1		Day 2			
		Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2
Bifluid	2-1	72.0		96		100			
		67.0		83		87			
		71.5		88		92			
		73.0		88		98			
		72.0		87		78			
		72.0		78		84			
		72.0		79		91			
		72.5		96		105			
		71.0		89		100			
		72.5		85		95			
	Mean	71.6	241.1	86.9	411.8	93.0	440.7	1.7080	1.8278
ORANGE	2-2	73.0		86		85			
		73.0		87		98			
		73.0		84		100			
		73.0		88		96			
		73.0		85		115			
		73.0		88		94			
		73.0		82		100			
		73.0		83		90			
		73.0		85		100			
		73.0		87		88			
	Mean	73.0	256.3	85.5	405.2	96.6	457.8	1.5809	1.7861

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Bifluid	2-2	72.0		87		108			
		67.0		81		100			
		71.5		95		109			
		73.0		86		118			
		72.0		89		118			
		72.0		90		108			
		72.0		88		111			
		72.5		87		95			
		71.0		83		82			
		72.5		87		87			
	Mean	71.6	241.1	87.3	413.7	103.6	491.0	1.7158	2.0364
ORANGE	2-3	73.0		85		89			
		73.0		82		115			
		73.0		88		100			
		73.0		85		100			
		73.0		79		107			
		73.0		80		98			
		73.0		80		97			
		73.0		81		106			
		73.0		81		94			
		73.0		86		96			
	Mean	73.0	256.3	82.7	391.9	100.2	474.8	1.5290	1.8525
Bifluid	2-3	72.0		105		97			
		67.0		88		100			
		71.5		92		92			
		73.0		89		96			
		72.0		87		86			
		72.0		91		97			
		72.0		89		98			
		72.5		87		99			
		71.0		80		83			
		72.5		89		100			
	Mean	71.6	241.1	89.7	425.1	94.8	449.3	1.7631	1.8635

		Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b]	
	Sample			Day 1		Day 2			
Agent	No.	Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2
ORANGE	3-1	36.5		39		43			
		36.5		40		40			
		36.5		39		41			
		36.5		40		39			
		36.5		40		40			
		36.5		38		45			
		36.5		38		42			
		36.5		37		41			
		36.5		39		44			
		36.5		41		41			
	Mean	36.5	128.1	39.1	185.3	40.7	192.9	1.4465	1.5058
Bifluid	3-1	38.0		37		39			
		38.5		44		43			
		39.0		37		39			
		38.0		37		45			
		37.5		37		44			
		38.0		38		43			
		38.0		38		43			
		38.5		38		44			
		38.5		41		42			
		38.0		41		38			
	Mean	38.2	128.6	38.8	183.9	42.0	199.0	1.4300	1.5474

ORANGE	3-2	36.5		40		39			
		36.5		38		40			
		36.5		41		38			
		36.5		41		40			
		36.5		40		42			
		36.5		40		39			
		36.5		44		40			
		36.5		40		42			
		36.5		39		39			
		36.5		47		45			
	Mean	36.5	128.1	41.0	194.3	40.4	191.5	1.5167	1.4949
Bifluid	3-2	38.0		44		45			
		38.5		41		44			
		39.0		41		46			
		38.0		46		42			
		37.5		40		42			
		38.0		43		46			
		38.0		47		43			
		38.5		48		45			
		38.5		42		35			
		38.0		42		49			
	Mean	38.2	128.6	43.4	205.7	43.7	207.1	1.5995	1.6104
ORANGE	3-3	36.5		42		38			
		36.5		45		46			
		36.5		41		48			
		36.5		50		41			
		36.5		45		40			
		36.5		44		43			
		36.5		44		41			
		36.5		41		43			
		36.5		43		41			
		36.5		42		39			
	Mean	36.5	128.1	43.7	207.1	42.0	199.0	1.6167	1.5534

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b]	
				Day 1		Day 2			
		Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2
Bifluid	3-3	38.0		47		43			
		38.5		42		50			
		39.0		40		46			
		38.0		43		44			
		37.5		39		55			
		38.0		36		50			
		38.0		44		51			
		38.5		36		51			
		38.5		46		45			
		38.0		41		50			
	Mean	38.2	128.6	41.4	196.2	48.5	229.8	1.5248	1.7869

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
  1) For spherical drop measurements:
    a) Vickers Eyepiece #1 (5X objective), k = 3.5104 for all ORANGE samples.
    b) Vickers Eyepiece #2 (5X objective), k = 3.367 for all Bifluid samples.
  2) For leaf spot measurements:
    a) 12.5X Filar Eyepiece #2 (2X objective), k = 4.901 for Sample 1.
    b) 12.5X Filar Eyepiece #1 (2X objective), k = 4.739 for Samples 2 and 3.

b. Spherical drop diameters divided into leaf spot diameters.

APPENDIX X

LIVE OAK RAW DATA ANALYSIS

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b]	
				Day 1		Day 2			
		Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2
ORANGE	1-1	140.5		171		200			
		140.5		170		183			
		140.5		180		189			
		140.5		192		197			
		140.5		175		200			
		140.5		177		193			
		140.5		183		211			
		140.5		180		196			
		140.5		170		198			
		140.5		169		205			
	Mean	140.5	493.2	176.7	837.4	197.2	934.5	1.6978	1.8947
Bifluid	1-1	152.5		200		248			
		154.0		207		221			
		149.5		185		210			
		151.5		197		200			
		154.5		184		208			
		156.0		193		191			
		154.0		227		207			
		151.5		227		193			
		152.5		200		194			
		149.5		220		221			
	Mean	152.6	513.8	204.0	964.9	209.3	991.9	1.8779	1.9305

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2
ORANGE	1-2	140.5		168		191			
		140.5		195		196			
		140.5		186		197			
		140.5		182		171			
		140.5		168		171			
		140.5		182		187			
		140.5		207		185			
		140.5		187		198			
		140.5		176		186			
		140.5		175		172			
	Mean	140.5	493.2	182.6	863.7	185.4	878.6	1.7512	1.7814
Bifluid	1-2	152.5		210		200			
		154.0		195		200			
		149.5		207		247			
		151.5		180		224			
		154.5		234		235			
		156.0		236		230			
		154.0		197		215			
		151.5		205		249			
		152.5		212		226			
		149.5		213		218			
	Mean	152.6	513.8	208.9	990.0	224.4	1063.4	1.9268	2.0696

ORANGE	1-3	140.5		200		225			
		140.5		208		239			
		140.5		250		113			
		140.5		273		254			
		140.5		200		211			
		140.5		243		268			
		140.5		219		217			
		140.5		200		240			
		140.5		226		232			
		140.5		185		218			
	Mean	140.5	493.2	220.4	1044.5	221.7	1050.6	2.1178	2.1301
Bifluid	1-3	152.5		170		191			
		154.0		200		179			
		149.5		200		218			
		151.5		198		204			
		154.5		209		200			
		156.0		226		200			
		154.0		204		232			
		151.5		200		200			
		152.5		194		208			
		149.5		160		240			
	Mean	152.6	513.8	196.1	929.3	207.2	981.9	1.8086	1.9110
ORANGE	2-1	71.0		82		84			
		71.0		88		78			
		71.0		77		80			
		71.0		78		85			
		71.0		80		87			
		71.0		80		89			
		71.0		84		83			
		71.0		81		84			
		71.0		82		87			
		71.0		71		85			
	Mean	71.0	249.2	80.3	380.5	84.2	399.0	1.5268	1.6011

		Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b/]	
				Day 1		Day 2			
Agent	Sample No.	Div.[a/]	Microns	Div.[a/]	Microns	Div.[a/]	Microns	Day 1	Day 2
Bifluid	2-1	76.0		74		90			
		78.5		65		89			
		78.0		65		90			
		77.5		75		89			
		76.5		92		100			
		76.5		100		120			
		77.5		91		100			
		78.5		114		97			
		80.0		84		96			
		79.0		92		89			
	Mean	77.8	262.0	85.2	403.8	96.0	454.9	1.5412	1.7362
ORANGE	2-2	71.0		93		94			
		71.0		84		88			
		71.0		88		108			
		71.0		86		95			
		71.0		113		100			
		71.0		100		100			
		71.0		104		100			
		71.0		92		100			
		71.0		88		100			
		71.0		100		92			
	Mean	71.0	249.2	94.8	449.3	97.7	463.0	1.8029	1.8579

Bifluid	2-2	76.0		84		82			
		78.5		100		100			
		78.0		86		103			
		77.5		100		131			
		76.5		100		105			
		76.5		83		110			
		77.5		85		109			
		78.5		84		100			
		80.0		80		108			
		79.0		76		97			
	Mean	77.8	262.0	87.8	416.1	104.5	495.2	1.5881	1.8900
ORANGE	2-3	71.0		68		78			
		71.0		78		103			
		71.0		78		91			
		71.0		85		97			
		71.0		112		96			
		71.0		80		86			
		71.0		79		80			
		71.0		90		87			
		71.0		78		83			
		71.0		100		75			
	Mean	71.0	249.2	84.8	401.9	90.3	427.9	1.6127	1.7170
Bifluid	2-3	76.0		88		111			
		78.5		93		100			
		78.0		91		92			
		77.5		76		95			
		76.5		76		150			
		76.5		76		170			
		77.5		94		141			
		78.5		95		111			
		80.0		80		118			
		79.0		88		119			
	Mean	77.8	262.0	85.7	406.1	120.7	572.0	1.5500	2.1832

Agent	Sample No.	Spherical Drop Diameter Div.[a]	Spherical Drop Diameter Microns	Leaf Spot Diameter Day 1 Div.[a]	Leaf Spot Diameter Day 1 Microns	Leaf Spot Diameter Day 2 Div.[a]	Leaf Spot Diameter Day 2 Microns	Spread Factor[b] Day 1	Spread Factor[b] Day 2
ORANGE	3-1	37.5		47		35			
		37.5		41		47			
		37.5		33		45			
		37.5		38		45			
		37.5		39		40			
		37.5		37		36			
		37.5		40		36			
		37.5		46		45			
		37.5		46		52			
		37.5		39		39			
	Mean	37.5	131.6	40.6	192.4	42.0	199.0	1.4620	1.5121
Bifluid	3-1	40.0		49		65			
		39.0		52		64			
		40.0		53		66			
		40.0		55		84			
		38.5		56		72			
		39.0		59		68			
		39.5		60		68			
		40.0		50		61			
		39.5		58		65			
		40.5		57		58			
	Mean	39.6	133.3	54.9	260.2	67.1	318.0	1.9519	2.3855

ORANGE	3-2	37.5		37		43			
		37.5		38		44			
		37.5		43		38			
		37.5		39		41			
		37.5		45		37			
		37.5		40		35			
		37.5		41		36			
		37.5		40		43			
		37.5		38		34			
		37.5		37		39			
	Mean	37.5	131.6	39.8	188.6	39.0	184.8	1.4331	1.4042
Bifluid	3-2	40.0		37		40			
		39.0		35		44			
		40.0		37		47			
		40.0		42		37			
		38.5		39		37			
		39.0		37		42			
		39.5		45		38			
		40.0		40		40			
		39.5		37		42			
		40.5		39		40			
	Mean	39.6	133.3	38.8	183.9	40.7	192.9	1.3795	1.4471
ORANGE	3-3	37.5		39		35			
		37.5		36		37			
		37.5		32		37			
		37.5		35		40			
		37.5		33		38			
		37.5		35		37			
		37.5		30		35			
		37.5		33		41			
		37.5		36		38			
		37.5		38		33			
	Mean	37.5	131.6	34.7	164.4	37.1	175.8	1.2492	1.3358

Agent	Sample No.	Spherical Drop Diameter		Leaf Spot Diameter				Spread Factor[b]	
				Day 1		Day 2			
		Div.[a]	Microns	Div.[a]	Microns	Div.[a]	Microns	Day 1	Day 2
Bifluid	3-3	40.0		52		61			
		39.0		55		62			
		40.0		63		67			
		40.0		53		72			
		38.5		53		67			
		39.0		55		78			
		39.5		50		57			
		40.0		58		67			
		39.5		56		60			
		40.5		54		81			
	Mean	39.6	133.3	54.9	260.2	67.2	318.5	1.9519	2.3893

a. Divisions referred to are those on the micrometer eyepiece of the microscope. Divisions times conversion factor constant (k) equals microns for microscope objectives used as follows:
   1) For spherical drop measurements:
      a) Vickers Eyepiece #1 (5X objective), k = 3.5104 for all ORANGE samples.
      b) Vickers Eyepiece #2 (5X objective), k = 3.367 for all Bifluid samples.
   2) For leaf spot measurements, 12.5X Filar Eyepiece #1 (2X objective), k = 4.739 for all samples.

b. Spherical drop diameter divided into leaf spot diameters.

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13. ABSTRACT

A spread factor calibration study was performed to correlate the spherical drop sizes of both ORANGE and Stull Bifluid defoliants with the spot sizes they produced by absorption and spreading on Kromekote cards. The results of this study show that the spread factor gradually increases for both defoliants with increasing drop size. Statistical treatment of the data was performed to obtain best-fit line plots for both materials. Best-fit line equations are statistically different for ORANGE and Stull Bifluid data. These differences may be small enough to be of little practical significance. Spread factor studies were performed employing mixtures of Bifluid #2 and Bifluid #1 at ratios of 13:1 and 17:1. The spread factors for these mixtures were not significantly different from that for the standard 15:1 Stull Bifluid mixture. A study was also made to compare the spread of ORANGE and Bifluid drops on leaves of various plant species. The results of this study were highly variable but indicated that, on the average, Stull Bifluid drops spread slightly more than ORANGE drops. This small average difference in drop spread may not be of practical significance.

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Defoliant drop size						
Spread factor study						
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ORANGE						
2,4-Dichlorophenoxyacetic acid, _n_-butyl ester						
2,4,5-Trichlorophenoxyacetic acid, _n_-butyl ester						
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Phaseolus vulgaris var. Black Valentine						
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DOI	1
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C	1
DTCL	1
OA	1
DO	1

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ATG	1
ATC	1
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